Kingscote (K.I) Exchange

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TECHNICAL TRAINING PUBLICATION

Engineering Training Group, 6 Flinders Street, Melbourne, Victoria, 3000

INTRODUCTION TO TELECOM ENGINEERING.

PART 2.

TELEPHONES AND TELEPHONE EXCHANGES.

(PREVIOUSLY CP 109)

Issued 1958.

1. TELEPHONES.

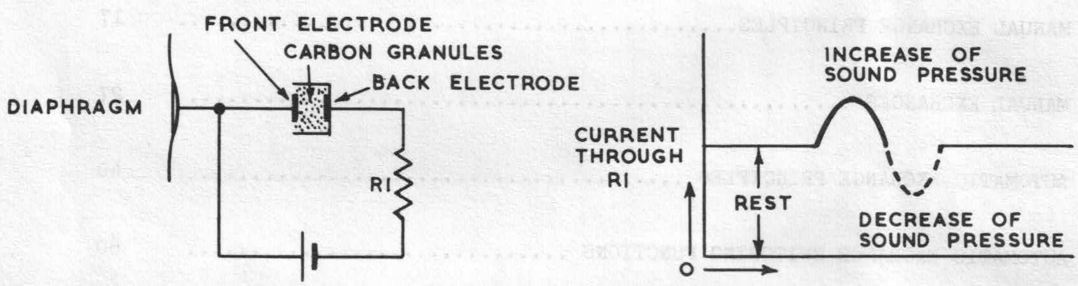
1.1 A telephone is a device for converting the energy of sound waves in speech to electric energy and for reconverting such energy when received back into sound. A practical telephone must also provide means for the subscriber to obtain connection to other subscribers and be called by them. This requires an electrical connection or line to a telephone exchange, also a means of signalling at both ends of the line preparatory to speaking, and a means of receiving such signals. The basic requirements are - transmitting, receiving, signalling.

1.2 The source of the electric energy may be either a local battery at the telephone (Magneto working) or a central battery at the exchange (C.B. working). There are two types of C.B. exchange - manual and automatic - and therefore two types of C.B. telephone - manual and automatic - which differ only in the method of signalling from the telephone. By usage, however, the telephones are known as C.B. and automatic respectively, but it should be remembered that both are central battery instruments.

1.3 Transmitting. The telephone transmitter when spoken into, regulates the current from the battery in such a way as to produce an electric speech signal which contains all the essential characteristics (frequency, volume, etc.) of the sound waves acting on it. The modern carbon transmitter (or microphone) has the desired features for telephone use. These are -

- Electrical output sufficiently high so that special amplifiers are not required except for long distance calls.
- Ruggedness.
- Output largely independent of the position in which it is held.
- Sufficiently low distortion of the signal.
- Reasonably cheap.

The basic construction of this transmitter is shown in Fig. 1a. It consists of a small cup partly filled with carbon granules and a front electrode insulated from the cup, and attached to a thin diaphragm.

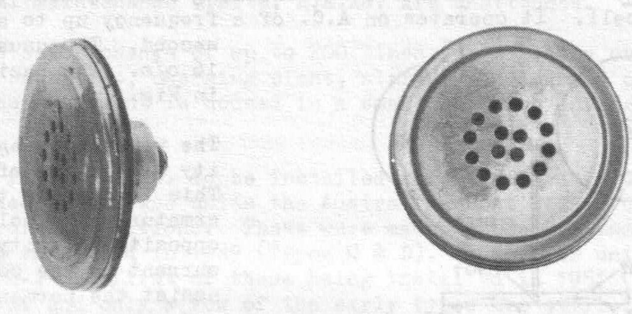


(a) (b)

FIG. 1.

With the transmitter connected in the electrical circuit shown, and with no sound waves striking the diaphragm, a steady current flows through the circuit. When sound waves strike the diaphragm, increases of sound pressure cause the diaphragm to move in, increasing the pressure on the carbon granules. This reduces the resistance of the transmitter and hence increases the flow of current through the circuit. Decreases in sound pressure allow the diaphragm to move out reducing the pressure on the carbon granules; this increases the resistance of the transmitter and hence reduces the flow of current through the circuit. These variations of current following the speech in frequency and volume constitute the electrical output signal. (See Fig. 1b.) Various modifications have been made to this simple transmitter over a number of years to improve it and make it cheaper; however, the basic principle of operation remains the same.

Fig. 2 shows a modern inset type transmitter.



(a) Side View. (b) Front View.

FIG. 2. MODERN TRANSMITTER INSET.

It would not be making the most effective use of the varying current signal if R_1 shown in Fig. 1a consisted of the line and distant receiver as in Fig. 3.

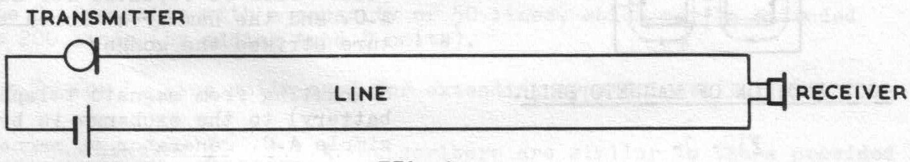


FIG. 3.

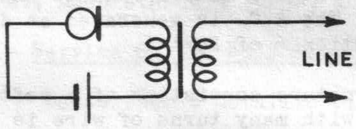


FIG. 4.

The signal is actually A.C. superimposed on the D.C. from the battery. In a local battery telephone the D.C. can be kept from flowing in the line (the resistance of which would severely limit its value) by the use of a transformer or induction coil as it is called. (See Fig. 4.)

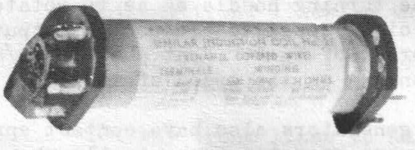


FIG. 5. MODERN TELEPHONE INDUCTION COIL.

A second use of the induction coil is that the A.C. speech signal is changed to a voltage more suitable for transmission over the comparatively high resistance line. With central battery telephones the D.C. must flow in the line, but a higher voltage is used (50 V) which ensures sufficient transmitter current. An induction coil is still required for the second reason. A modern induction coil is shown in Fig. 5.

1.4 Receiving. The A.C. speech signals are changed back to sound at the receiving end by the receiver. This is an electromagnetic device wherein the A.C. signals passing through the operating coils cause corresponding movements of an iron diaphragm to regenerate the sound waves.

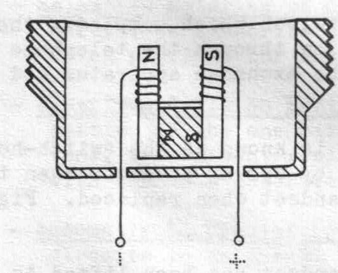
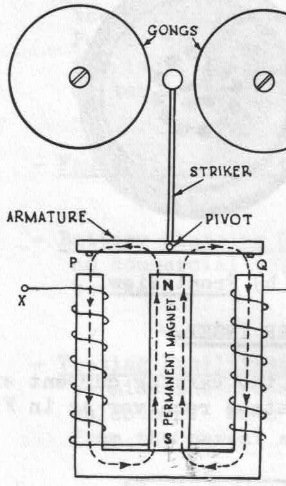


FIG. 6. RECEIVER BASIC CONSTRUCTION.

Fig. 6 shows the basic construction of a common type of receiver. A small permanent magnet is always included and the magnetism caused by the A.C. signal in the coils adds to and subtracts from the pull of the magnet on the diaphragm.

This gives a less distorted and louder output than if no magnet were used. Some modern receivers use a separate iron armature which is coupled to a light diaphragm.

1.5 Signalling. The bell used for the incoming ring on most telephones is called a magneto bell. It operates on A.C. of a frequency up to about 40 cycles per second. The usual frequency used is 16 c/s. The basic construction is shown in Fig. 7.

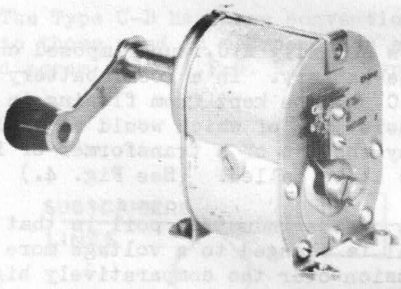


CONSTRUCTION OF MAGNETO BELL.

FIG. 7.

The permanent magnet causes a like polarity at the end of each of the coils. This induces in the ends of the soft iron armature like poles also, but of the opposite polarity to the coil poles. A current in the coils in one direction will assist the permanent magnetism on one side and oppose it on the other which will mean the pivoted armature will tilt to the stronger pole. The current reverses on the next half-cycle of A.C., the weaker pole becomes stronger and vice versa which causes the armature to tilt to the other pole. This is repeated for each cycle of A.C. and the hammer attached to the armature strikes the gongs.

Signalling from magneto telephones (local battery) to the exchange is by means of a simple A.C. generator or magneto.



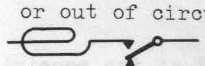
MAGNETO HAND GENERATOR.

FIG. 8

Fig. 8 shows a modern magneto hand generator. The A.C. is generated as described in Section 6 of Part 1.

The armature consisting of a soft iron core wound with many turns of wire is rotated in the magnetic field of one or more permanent magnets. The armature is geared to the turning handle so as to rotate at sufficient speed to produce an output of the order of 70-100 V at about 20 c/s (depending on the speed of turning).

Hand generators also have contact springs which are operated mechanically when the handle is turned and restored to normal when the handle is released. The contacts automatically switch the armature into or out of circuit as required. The circuit symbol for a generator is

 the off-normal springs as they are called being represented by the change-over contacts on the right.

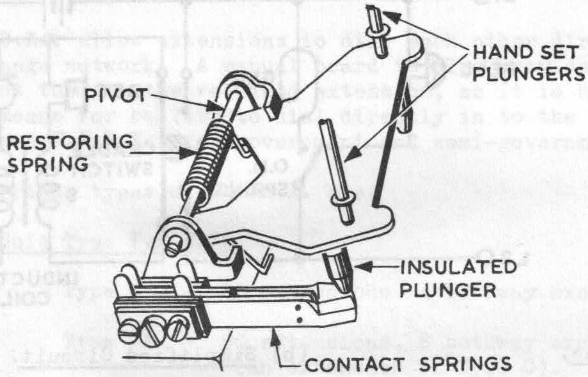
Signalling for C.B. telephones is by means of a switch which completes the circuit when the handset is lifted allowing current to flow through the telephone from the exchange battery. This current is detected by the exchange apparatus and a lamp glows on the switchboard.

All telephones have this switch, however, and it is known as the switch-hook, cradle switch or hook switch. It is switched on by spring pressure when the handset is lifted and off by the weight of the handset when replaced. Fig. 9 shows the principle of operation.

Signalling from automatic telephones after the handset has been lifted is by means of a dial which transmits signals to the exchange apparatus under the control of the subscriber. The dial is also a switch which opens and closes the D.C. circuit to the exchange depending on the number dialled. If 6 is dialled the circuit is

opened 6 times in quick succession; if 2 is dialled, it is opened twice, and if 0, 10 times. The rate of signalling is 10 breaks of the circuit or 10 pulses (or impulses) per second.

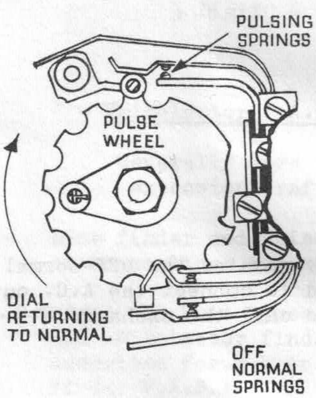
The length of time occupied by each pulse is important and for a correctly adjusted dial each break pulse is 66 mS (a millisecond is 1/1000th of a second) and each make pulse between successive breaks is 33 mS.

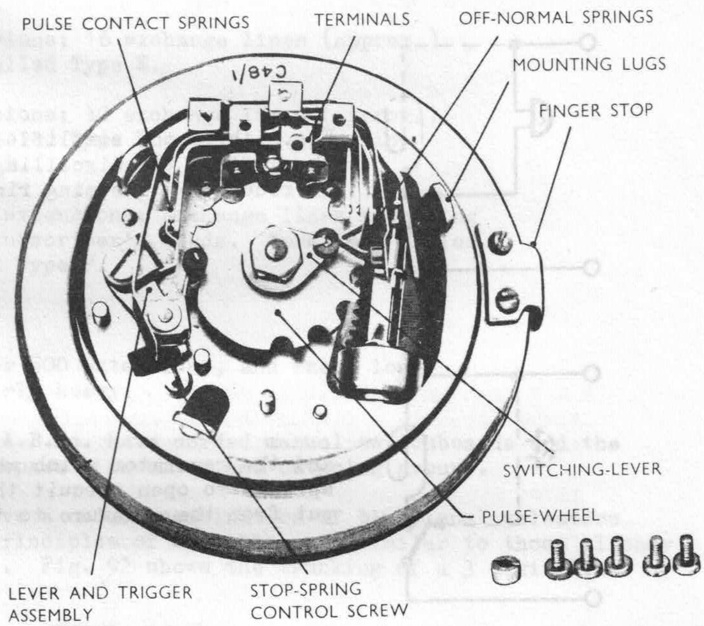


SWITCH-HOOK.

FIG. 9.

The principle of generating these pulses is shown in Fig. 10a.





(a) Basic Operation. (b) Modern Dial - Rear View.

TELEPHONE DIAL.

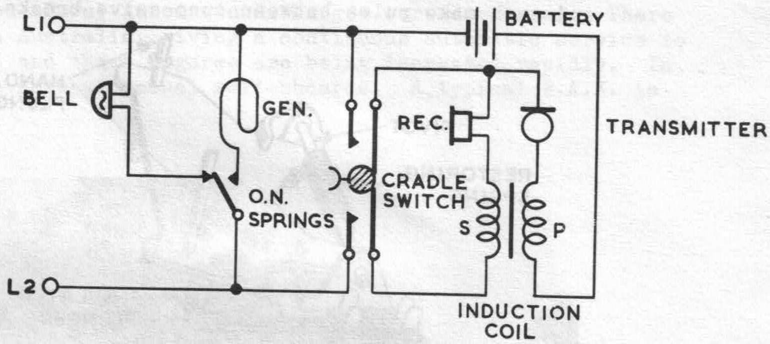
FIG. 10.

The pulses are transmitted to line as the dial is allowed to return to the normal position under the force of a clock spring, at a speed kept constant by the governor.

Two extra sets of contacts are included in the dial mechanism and these operate when the dial is pulled around from its normal position, and restore when the dial has returned fully to normal. They are called off-normal springs. They are also simple switches and have auxiliary functions to be dealt with later.

1.6 Magneto Telephone. Basic Operation.

(a) Modern Magneto Telephone.



(b) Simplified Circuit.

FIG. 11.

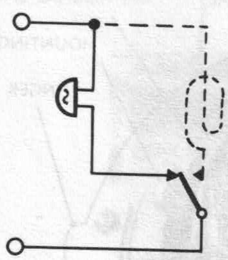
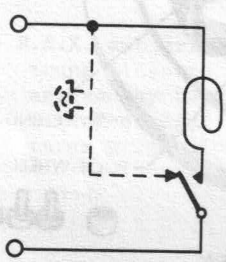
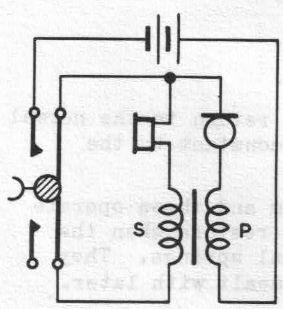


Fig. 11b is the simplified circuit of a magneto telephone. On the left is the signalling circuit consisting of the bell ready to receive an incoming ring -



and the generator which when turned operates the off-normal springs to open circuit the bell and to connect the A.C. output from the armature to the line to call the exchange.



On the right of Fig. 11b is the speaking circuit consisting of the transmitter local circuit and the receiver circuit coupled together for sending speech by means of the induction coil. The cradle switch contacts serve to disconnect the local transmitter circuit and the receiver circuit when the telephone is not in use.

1.7 C.B. Telephone. Basic Operation. Fig. 12 is the simplified circuit of a central battery (C.B.) manual telephone and Fig. 13 the simplified circuit of a C.B. automatic telephone.

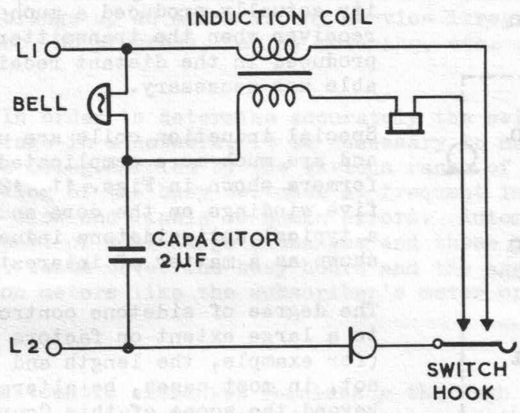


FIG. 12. SIMPLIFIED CIRCUIT C.B. TELEPHONE.

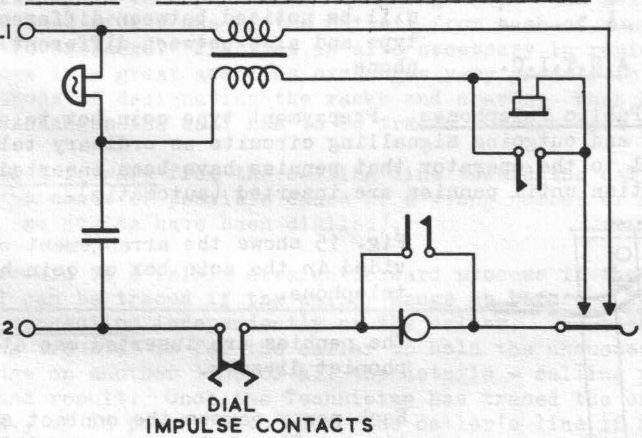


FIG. 13. AUTOMATIC TELEPHONE SIMPLIFIED CIRCUIT.

Except for the signalling functions performed by the dial on outgoing calls from the automatic telephone, their operation is identical.

Incoming ring is received on the bell via the 2 µF capacitor.

The D.C. is supplied from the central battery at the exchange and when the handset is lifted the current flows in the transmitter circuit but is blocked from the receiver circuit by the capacitor. The transmitter circuit and receiver circuit are coupled together by the induction coil for the best transmission and reception of the A.C. speech currents.

The capacitor allows A.C. ringing and speech currents to pass but blocks D.C. from the receiver and bell where it is not wanted. When the handset is on the cradle the telephone is open circuit to D.C. so that no current is taken from the central battery if the telephone is not in use.

The dial generates the signalling pulses simply by opening the D.C. transmitter circuit the required number of times depending on the digit dialled.

During dialling the off-normal springs automatically short circuit the transmitter circuit to give a lower resistance in the dialling circuit and also short circuit the receiver to prevent dialling clicks being heard.

1.8 Sidetone Reduction. In all modern telephones, another facility is provided which is designed to reduce the loudness of local speech and noise reproduced in the local receiver. All early telephones without this facility actually produced a much louder signal in the local receiver when the transmitter was spoken into than was produced in the distant receiver. This is neither desirable nor necessary.

Special induction coils are used to reduce this sidetone and are much more complicated than the simple transformers shown in Figs. 11, 12 and 13. Most have at least five windings on the core and the circuit arrangement of a typical anti-sidetone induction coil (A.S.T.I.C.) is shown as a matter of interest only in Fig. 14.

The degree of sidetone control achieved, however, depends to a large extent on factors outside the telephone itself (for example, the length and type of line) and which cannot, in most cases, be altered. A discussion of this is beyond the scope of this Course but it is for these reasons that a considerable difference in sidetone level will be noticed between different telephones of the same type and also between different calls on the one telephone.

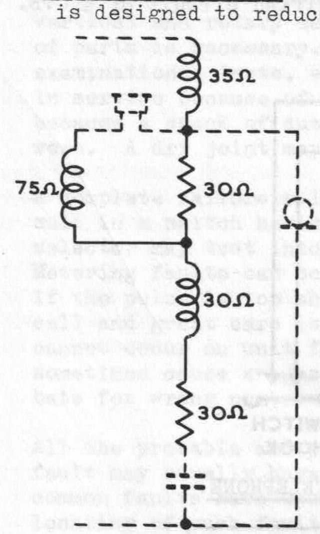


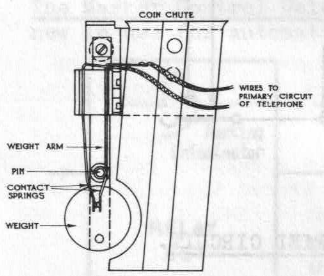
FIG. 14. A.S.T.I.C.

1.9 Unit Fee Public Telephones. Prepayment type coin box telephones use the same speaking and outgoing signalling circuits as ordinary telephones with additions to signal to the operator that pennies have been inserted (manual) or to prevent conversation until pennies are inserted (automatic).

Fig. 15 shows the arrangement of the coin chute as provided in the coin box or coin head of a manual public telephone.

The pennies are inserted one at a time when the telephonist directs.

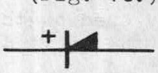
Each penny causes the contact springs to vibrate a few times. The springs are wired in series with the transmitter and in opening and closing the D.C. circuit rapidly cause a buzz which is heard by the telephonist.



PUBLIC TELEPHONE COIN CHUTE.

FIG. 15.

Unit fee automatic public telephones are now of the variable tariff type. This means that the coin heads may be readily adjusted for fees between one and four pennies. Basically they operate as follows:- The caller dials the required number in the usual manner. When the subscriber answers, the automatic exchange equipment causes the polarity of the battery connected to the P.T. line to be reversed. This results in the P.T. circuit changing in such a way that what might be termed 'electrical blockages' prevent the caller from speaking to the called party. The caller, however, can hear the called party answer but at a reduced volume. The insertion of the pennies in succession operates a mechanical tripping mechanism which by means of contacts removes the blockages and allows the telephone circuit to function normally. Replacing the receiver or handset at the end of the call causes the mechanism to restore in readiness for the next call. The blockages referred to are produced by the use of small metal rectifiers in the circuit. (Fig. 16.)



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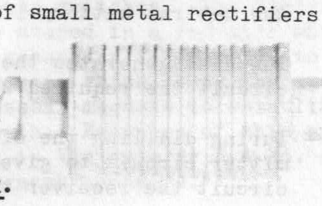


FIG. 16. SMALL METAL RECTIFIER.

These allow current to flow in one direction only and in the form shown in Fig. 16 are used extensively in telecom circuits. Fig. 17 shows in basic form how they prevent current in the P.T. transmitter after reversal of line polarity. With the line polarity shown, MRA is conducting, MRB non-conducting. After reversal MRA is non-conducting making the transmitter virtually open circuit. MRB conducts current to hold the exchange equipment. The coin springs short circuit MRA and open circuit MRB after the correct number of coins have been released into the mechanism.

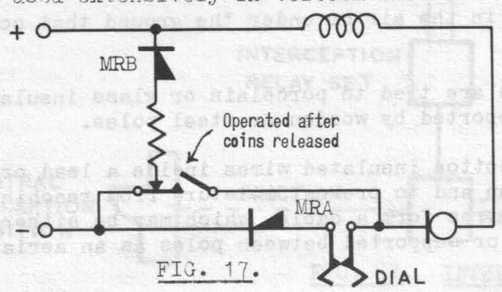
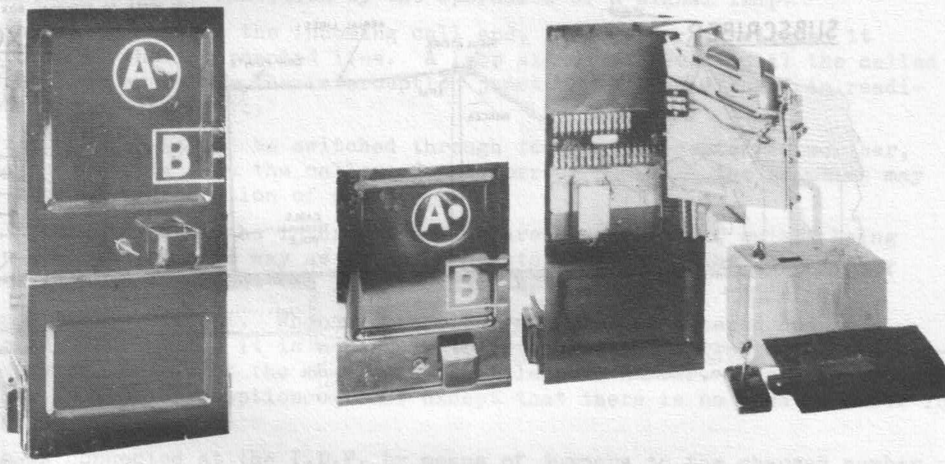


FIG. 17.

1.10 Multi-coin Public Telephones may be used for local calls, trunk calls or telegrams (phonograms). The one mechanism (Fig. 18) is used with different circuits for auto or C.B., magneto and R.A.X. areas.



(a) Multi-coin Attachment. (b) Component Parts of Attachment.

FIG. 18.

For trunk calls and telegrams the required fee is inserted at the direction of the operator in a combination of pennies, sixpences and shillings. Coin signals are transmitted from the mechanism to the operator by means of an auxiliary transmitter - a penny strikes a wire gong once; a sixpence strikes a bell gong once; a shilling strikes the bell gong twice. After the coins are inserted the mechanism and circuit are controlled by two press buttons 'A' or 'B'. Their functions are:

- 'A' Pressed when requested by the operator on trunk, telegram, or local calls via manual exchanges. On local auto. calls pressed when the called party answers. A short circuit across the transmitter is removed when this button is pressed and conversation may proceed. Also the mechanism releases the coins finally into the coin tin.

- 'B' Pressed when requested by the operator on trunk, telegram, or local calls via manual exchanges (if correct fee is not heard by the operator).

  On local auto calls pressed if the called party is busy or not answering. (A unit fee must be inserted before dialling is effective). The coins are returned by the mechanism into the refund container. The mechanism is restored to the condition existing before the coins were inserted. A warning buzz is generated for approximately 7 seconds to warn the operator that B button has been pressed (in case B is pressed instead of A). After this buzz ceases, the caller and operator may converse.

In R.A.X. areas a special circuit and dial are used so that the parent exchange trunk operator may be called without first having to insert pennies.

2. TELEPHONE LINES.

2.1 Telephone lines (Fig. 19) are wires in the air or under the ground that connect telephones to exchanges.

Aerial or open wire telephone lines are tied to porcelain or glass insulators fitted on wooden arms which are supported by wooden or steel poles.

Other lines use paper, plastic or cotton insulated wires inside a lead or plastic sheath to give mechanical protection and to prevent moisture from reaching the insulation. One or more pairs of wires form a cable, which may be either buried in the ground as an underground cable or supported between poles as an aerial cable.

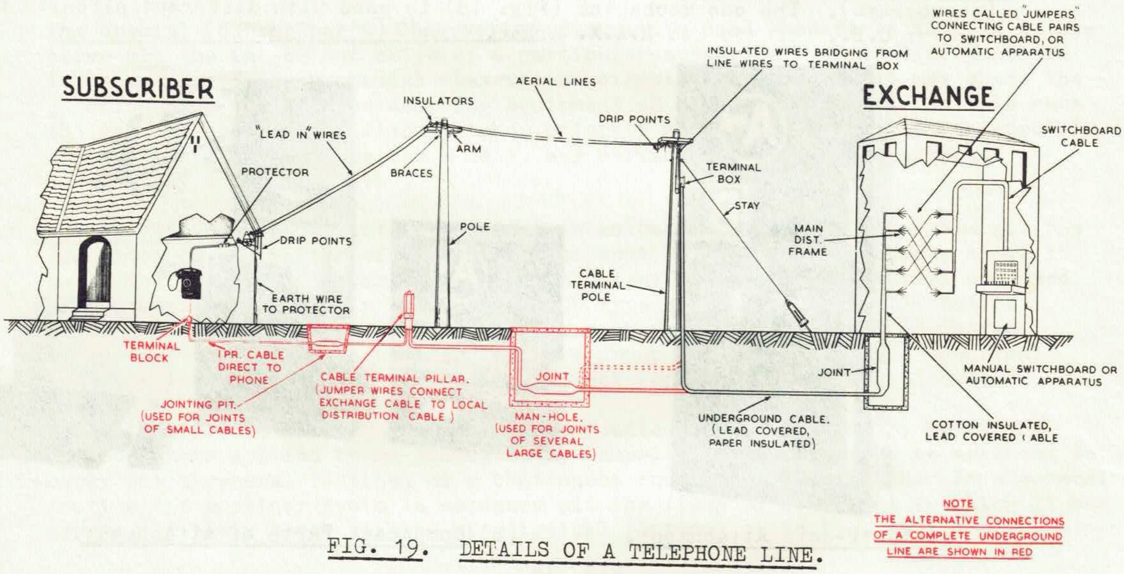


FIG. 19. DETAILS OF A TELEPHONE LINE.

A telephone line generally uses two wires, and this is called a metallic or two-wire circuit. When the earth (or the lead sheath of the underground cable, which is connected to earth) is used instead of one of the wires, the circuit is then an earth return or single-wire circuit. Earth return circuits may be used for some telegraph or signalling circuits, but are rarely used for telephone circuits, because they provide a noisy, inferior type of circuit.

For identification, the two conductors of telephone circuits are designated in various ways. They are, respectively -

Line 1 and Line 2, A and B, Positive (+) and Negative (-), or Tip and Ring.

A subscribers line connects the subscriber's telephone to the local exchange.

A line between two exchanges within the same unit fee area, is called a junction line.

A line between two exchanges not within the same unit fee area, is called a trunk line.

Combinations of these lines may be used to set up a telephone connection between two subscribers.

2.2 Conductors used for Telephone Lines. In general, copper or copper alloy wires are used because copper has low resistivity and sufficient strength to withstand the effects of wind and weather variations.

Copper wires are used for all cable lines.

The wires most commonly used for aerial lines are -

Hard Drawn Copper (H.D.C.) wire, made by drawing refined copper through steel dies. To obtain the maximum strength for the wire, the copper is drawn in the cold state.

Cadmium Copper (C.C.) wire, composed of copper alloyed with a small amount of cadmium. This wire is stronger but costs more than hard drawn copper wire.

In some country districts, Galvanised Iron (G.I.) aerial wires may be used on minor aerial line routes. G.I. wires are cheaper but, for equal weights, the resistance per mile is about six times that of copper. These wires, therefore, are generally of large cross-sectional area.

In some areas, aluminium aerial wires may be used. Although the resistivity of aluminium is higher, the resistance per mile of this wire, for equal weights, is less than that of copper wire.

2.3 Line and Loop Resistance. In C.B. manual and automatic telephone operation, the D.C. for the telephone transmitter is fed from the exchange battery over the subscriber's line. The conductor resistance and, therefore, the length of the line must not exceed specified limits otherwise the current will be too low and the transmitter will not operate satisfactorily.

The two wires of the line are in series as far as the current flow is concerned. Thus, the line resistance (sometimes called the loop resistance of the line) is twice the single wire resistance. It is measured from the exchange end with a short circuit across the line at the distant end.

The loop resistance of a telephone line and distant telephone is measured from the exchange end with the receiver off the switch-hook at the distant telephone.

The resistance per loop mile is the resistance of a line which is one mile long; that is, the total length of wire is two miles.

2.4 Electrical Hazards. Telephone cables and aerial wires may come in contact, either directly or indirectly, with foreign voltages and currents. These voltages and currents may cause damage to the telephone apparatus and wiring and to the cable or aerial wires. Lines which are completely in underground cable are far less likely to be affected by hazards than open wire lines.

The two hazards are:-

- Lightning, which is of extremely high voltage and may affect aerial lines within quite a large radius from the actual position of the 'strike' (up to $\frac{1}{2}$ mile or more).

- Electric supply lines with voltages ranging from 200 to 132,000 volts.

2.5 Protection against these hazards is a very important part of any telephone or telegraph circuit and is always provided at one or both ends of the line and sometimes also at the cable to aerial terminal pole.

There are two methods of protecting internal and external telephone plant, namely, mechanical protective devices or guards, electrically operated protective devices.

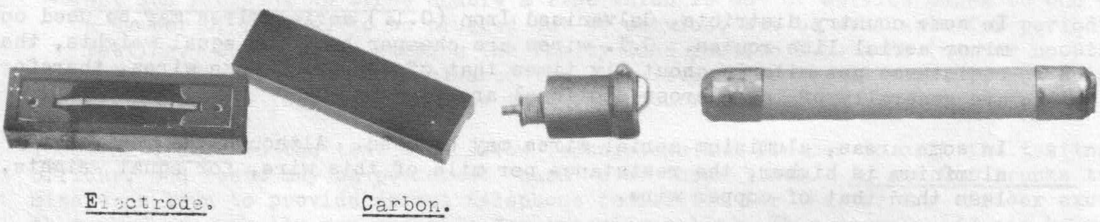
Examples of mechanical protective devices are the insulating bridge used when telephone cables cross electric light conduits or cables, and the minimum spacing of two inches between telephone cables and electric light conduits or cables, when the two are run parallel to each other.

Electrical protective devices are of two main types -

Devices which protect plant against the effects of excessive voltage.

Devices which protect plant against the effects of excessive current.

The protective devices normally used for safeguarding telephone lines and apparatus from excessive voltage and current conditions are Arresters, Heat Coils and Fuses. They remain unaffected by normal speech and signalling currents. The devices act automatically whenever the voltage or current in the telephone circuit is likely to damage the lines or apparatus. The line is either disconnected and the foreign current or voltage isolated, or a connection to earth is provided clear of the equipment.



Electrode. Carbon.

ARRESTER, HEAT COIL AND FUSE.

(Approximate Actual Size.)

FIG. 20.

Arresters provide a path to earth for dangerous foreign potentials. (See Figs. 23 and 26 for method of connection.) They are always used to protect indoor equipment on circuits which are provided by open wire lines, and they are fitted at the point where the outdoor wires enter the building. In some cases, arresters are used where open wires connect to an underground cable.

Normally, arresters conduct to earth most of the surges induced in external lines by lightning discharges. However, in the case of very heavy surges or direct strikes, the energy to be dissipated is so great that the arrester may be destroyed and the outdoor wires fused and insulators shattered. It is not possible to provide complete protection from direct strikes by lightning.

A modern arrester (see Fig. 20) comprises a carbon block paired with a moulded plastic block fitted with a phosphor-bronze blade or discharge piece. The edge of the moulded portion fits flush on the carbon block to exclude dust, and the gap between the blade and the carbon is carefully controlled to confine the breakdown voltage to the range desired, which is 750-1000 V.

Fuses. Basically, a fuse is a short section of wire having a low melting point and forming a part of the circuit requiring protection. The fuse melts and thus opens the circuit when excessive current flows. Since the action of fuses depends upon the heating effect of the current flowing through the circuit, fuses are not intended to protect against high voltages, but only to guard against the flow of currents of excessive values which might cause damage to apparatus connected to the circuit. A fuse is connected in each wire of all lines exposed to currents of excessive value. Fuses are inserted at the point where the exposed wiring is connected to the indoor wiring, and always on the line side of the arrester.

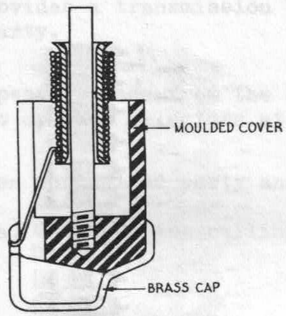
(a) Glass Tube. (b) Porcelain Tube.

FIG. 21. TUBULAR FUSES.

An efficient fuse should "blow" quickly, without scattering molten metal, as soon as the current rises to a value which may cause a fire or damage to apparatus or cables. Any arc which may occur when the fuse wire melts should not be maintained. Fuses for protectors are tubular (see Fig. 21) and the

fuse wire is contained in a glass, fibre or ceramic (porcelain) tube with metal end-caps to which this wire is soldered. They are 'rated' at 1.5 amperes or in some cases 3 amperes, and will fuse or 'blow' at a current of approximately twice their rated value.

Heat Coils. It is found that a current greater than 0.3 ampere, if allowed to flow through telephone equipment for a long enough time, damages that equipment by the heat produced. It is impracticable, however, to use a fuse which operates much below 3 amperes, because of the fine wire which has to be used in such a fuse. (The diameter of the fuse wire used in 1.5A fuses is approximately 0.003".) To protect the equipment from damage by currents too small to operate the fuses, Heat Coils are provided.



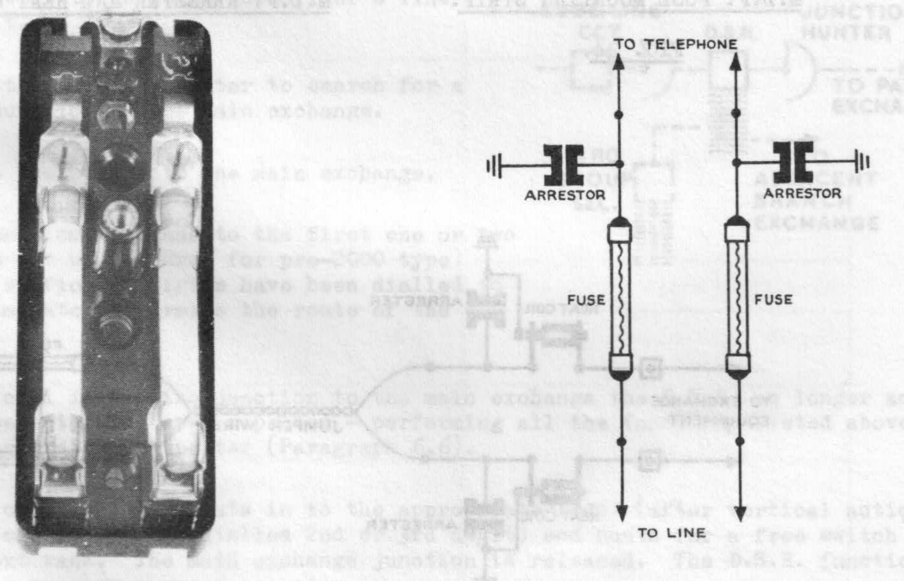
HEAT COIL.

FIG. 22.

(About 3 times actual size.)

The heat coil (see Fig. 22) is held in the protector by spring clips. The coil carries a current of 350 mA for 3 hours without operating, and operates within 210 seconds when 500 mA flows. In operating, the heat produced by excess current melts the soft solder and the spring clip forces the copper tube along the pin which then contacts a supplementary spring connected to earth, and the line is earthed without being disconnected. When the resulting line current is heavy, the fuse operates and isolates the apparatus.

2.6 Substation Protectors are fitted between the external and internal parts of a line whenever the line is wholly or partly of aerial construction (see Fig. 19). Fig. 23a shows a modern substation protector and Fig. 23b shows how it is connected in circuit.

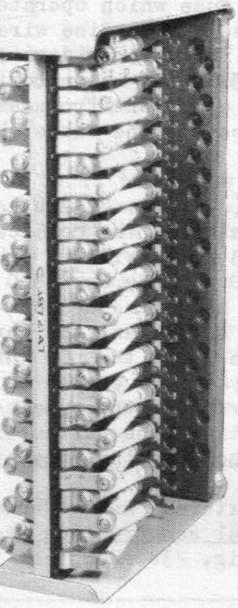


(a) (b)

FIG. 23. SUBSTATION PROTECTOR.

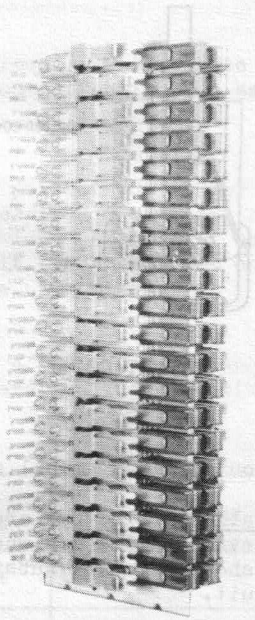
If the line is wholly underground, a simple terminal block is used instead at the subscriber's premises (in the case of a single service on a house).

2.7 M.D.F. At the exchange end of the line the protective devices are mounted on the main distributing frame (M.D.F.). Usually incoming cables are terminated on mountings of 20 or 25 pairs of fuses (Fig. 24), the exchange apparatus is wired to mountings of 20 pair arresters and heat coils (Fig. 25). A single twisted pair of wires of distinctive colour is used to connect each line between its set of fuses and arresters. These are called 'jumper' wires and provide a flexible (readily altered) connection between the external and internal plant. The circuit for one wire (leg) of the line at the M.D.F. is shown in Fig. 26.



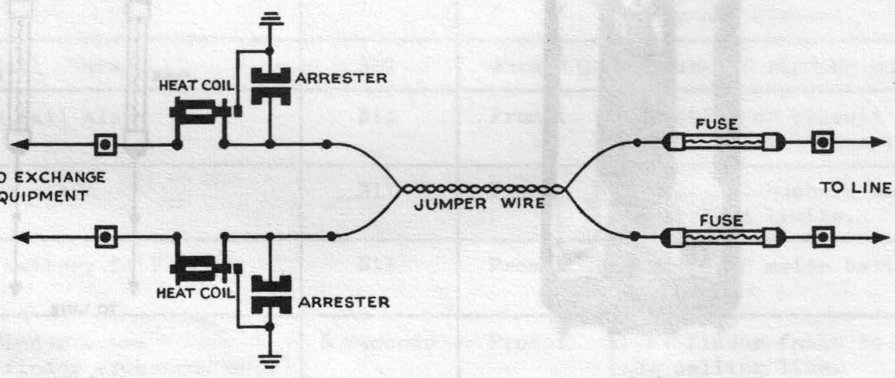
M.D.F. FUSE MOUNTING STRIP.

FIG. 24.



M.D.F. ARRESTER AND HEAT COIL STRIP.

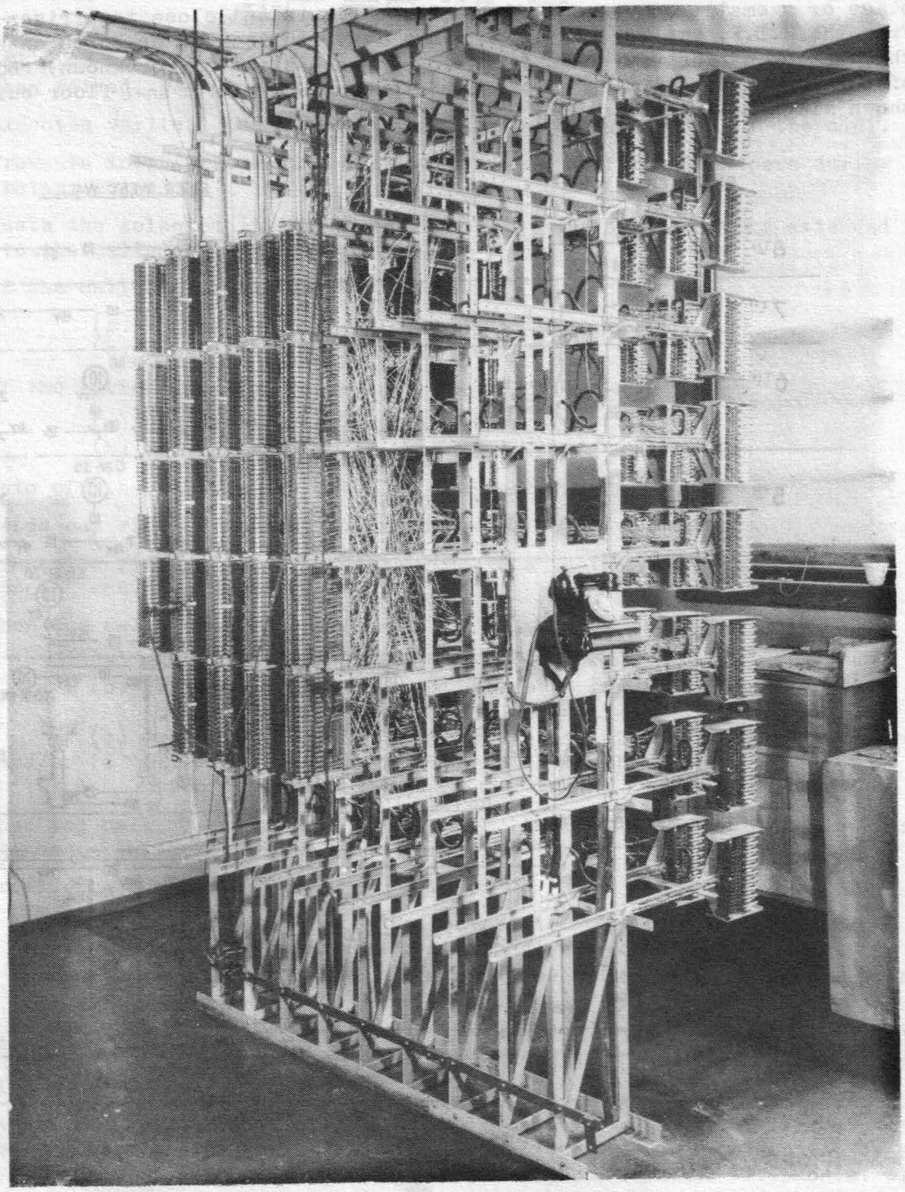
FIG. 25.



EXCHANGE M.D.F. CONNECTION.

FIG. 26.

Fig. 27 shows a typical M.D.F. for a small exchange (about 400 lines).



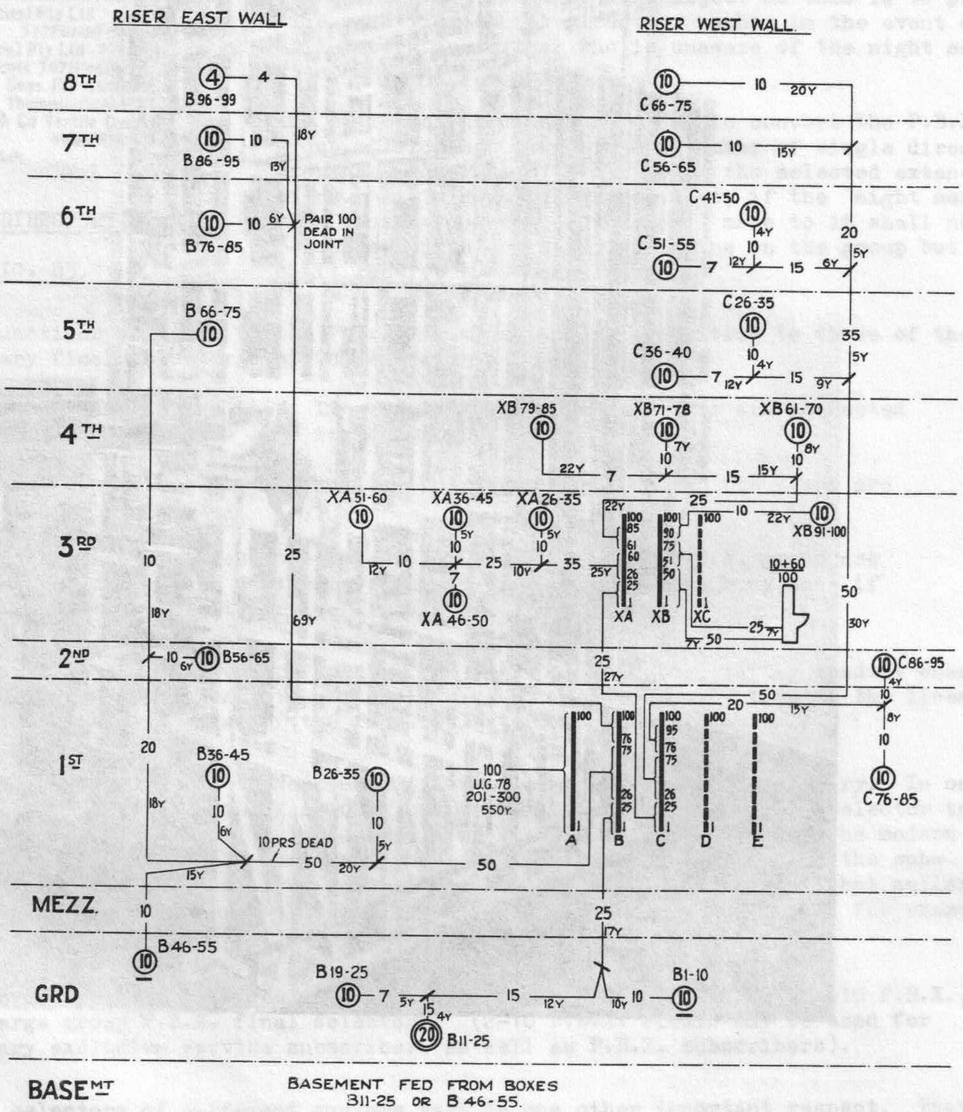
Note arresters, fuses, jumpers, underground cables, earth bar and cables to exchange apparatus and testing shoe.

FLOOR TYPE M.D.F.

FIG. 27.

2.8 Block Distribution. Large buildings containing many subscribers with differing telephone requirements are cabled during the construction of the building, in order to facilitate installation later and to avoid large cables being exposed to view and damage. One or more 'riser' shafts are usually provided which run between all the floors and enclose all inter-floor conduits and cables.

The underground cable from the street terminates on an M.D.F. in a convenient place or a small room on one of the lower floors and close to a riser shaft. From the M.D.F. smaller cables run to a distribution box or boxes on each floor, the size of cables and boxes depending on the estimated (or known) requirements of the tenants. A typical block distribution scheme for an 8 floor building is shown diagramatically in Fig. 28.



TYPICAL CABLING SCHEME FOR CITY BUILDING.

FIG. 28.

3. MANUAL EXCHANGE PRINCIPLES.

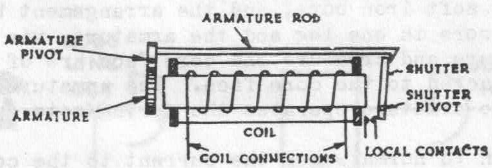
3.1 A manual telephone exchange must provide facilities for:

- Speaking (transmitting and receiving).
- Signalling (incoming and outgoing).
- Interconnecting the subscribers locally or originating connections to subscribers connected to distant exchanges.
- Supervision of connections including a clearing signal at the end of the call.
- An audible night alarm.
- Recording the calls made by the various subscribers for charging purposes.

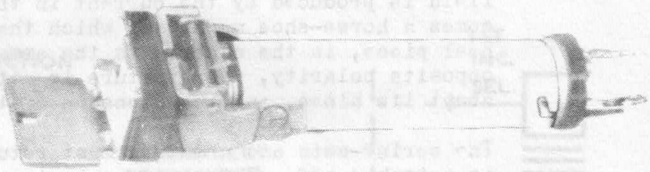
3.2 Speaking. The telephonist's circuit includes a telephone circuit. On larger switchboards the handset is replaced by an operator's set or head and breast set which is individual to each operator, who 'plugs' the set in to the switchboard. (See Fig. 57, page 33.) Both hands are left free.

3.3 Signalling. The A.C. ring from a calling subscriber is received on an indicator or drop shutter which gives the operator visual notice of the subscriber's number.

The indicator is simply an electromagnet, the armature of which releases a drop flap or shutter to expose the subscriber's number on a conspicuous background. Fig. 29a shows the principle and Fig. 29b shows a modern indicator.



(a) Principle of Operation.



(b) Typical Indicator.

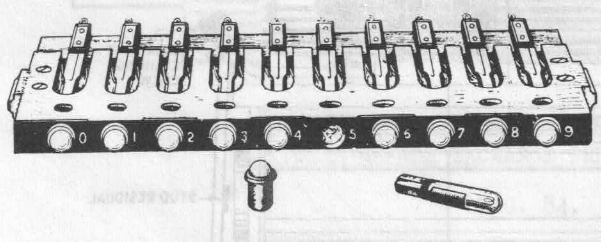
LINE INDICATOR.

FIG. 29.

The shutter when released operates electrical contacts which complete the circuit for an audible alarm (turned off when not required).

Lamp Signalling. With C.B. exchanges, subscriber signalling is by means of a lamp which lights when the subscriber lifts the handset and completes the D.C. loop for current to flow from the central battery at the exchange. The lamps are quite small and are inserted into strips of lamp sockets or jacks and covered by caps or 'opals' of frosted glass which may be made a distinctive colour for each purpose (Fig. 30).

The actual line current to the telephone may be used to light the lamp, but more often the line current is used to operate a relay which lights the lamp via a separate circuit.



LAMP, CAP AND LAMP JACK STRIP.

FIG. 30.

Relays. A relay is an electromagnetic device used for relaying changes in the condition of the circuit, of which it forms a part, to independent circuits. Essentially, the relay consists of a core, a yoke or heel piece, and a hinged armature, as in Fig. 31.

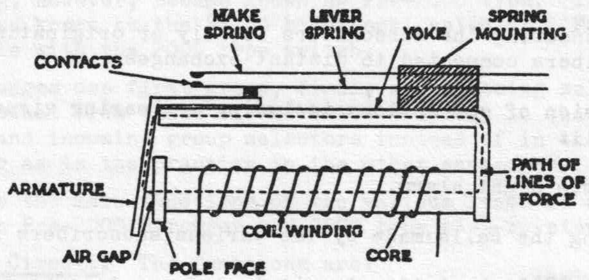


FIG. 31. MAIN ELEMENTS OF TELEPHONE RELAY.

These parts are all made of superior quality soft iron, although special materials are frequently used for the core to obtain some particular effect.

Wound on, but insulated from the core, are a number of turns of wire forming a coil of a resistance and cross-sectional area suitable for the circuit in which the relay is to work. Relays are usually operated from a D.C. source, although A.C. is used in some cases. When a current flows through the coil, the magnetic field is produced by the current in the soft iron core, and the arrangement becomes a horse-shoe magnet of which the core is one leg and the armature, via the heel piece, is the other. As the armature and armature end core face are of opposite polarity, the armature is attracted to the core face. The armature moves about its hinge, and an extension of the armature operates the spring-sets.

The spring-sets and armature must return to normal when the current to the coil is switched off. This is done by tensioning the springs moved directly by the armature (termed lever springs) against the armature, so that, when the attractive force between the armature and core ceases on the decay of the coil current and flux, this tension restores the armature to normal. To prevent any possibility of the armature "sticking" to the core due to the effects of residual magnetism, the armature carries a non-magnetic residual screw or stud. This prevents the armature from coming into direct contact with the core face.

Most relays have more than one set of contacts; some have as many as eight contact units. Fig. 32 shows a relay typical of those used extensively in C.B. and automatic exchanges.

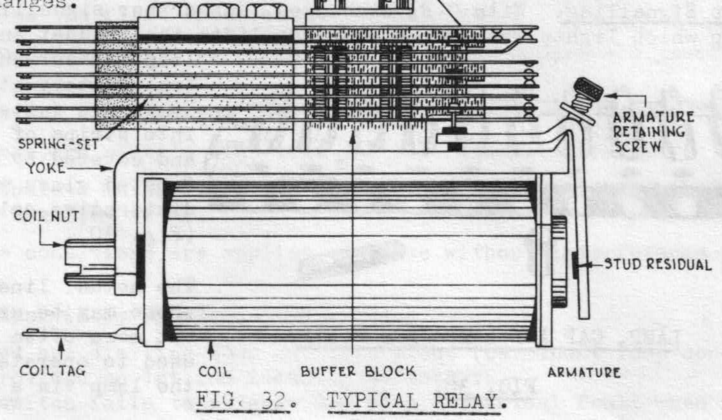
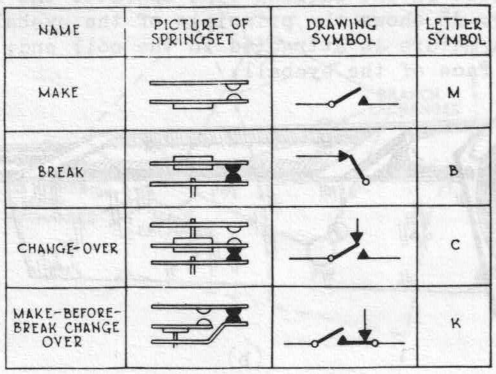


FIG. 32. TYPICAL RELAY.



Typical spring combinations are shown in Fig. 33. The title of the make and break springs, depends upon the operated condition of the contacts. The difference between the change-over and the make-before-break is that, in the case of a make-before-break assembly, the "break" contacts are not broken until the make contacts are made.

FIG. 33. CONTACT SPRING UNITS.

Relays often have more than one winding - sometimes as many as three operating coils. Fig. 34 shows the drawing symbol for typical relays as used in schematic circuits. The figure in the symbol is to indicate the resistance value of the coil or coils, this value depending on the circuit requirements. By means of special design, the details of which need not concern us here, relays may be made to operate and release more slowly than normal (slow acting) or to only release more slowly.

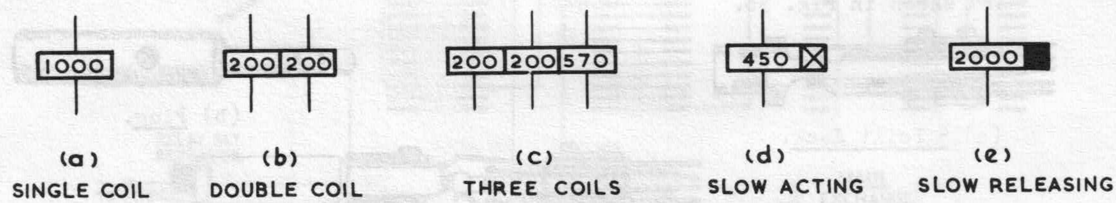
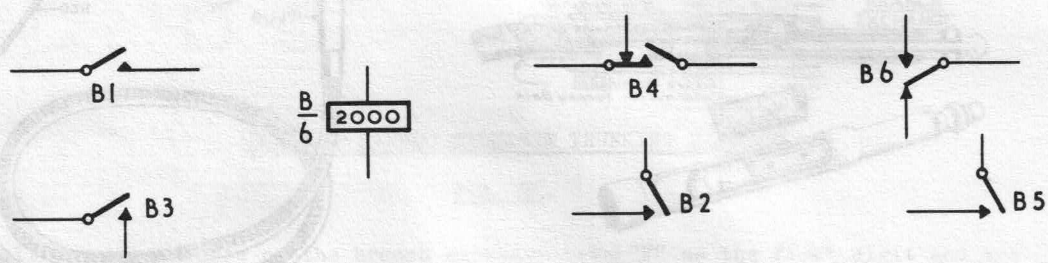


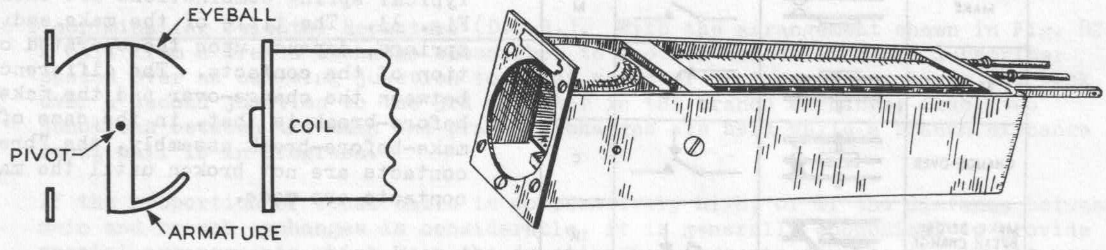
FIG. 34. RELAY SYMBOLS.

Because some circuits in telephony use many relays (30 or more is quite common), it is not convenient on schematic circuit drawings to show a relay with all its contact units close to it. The contacts are identified by standard symbols and are detached from the relay and each other so that the circuit is easier to 'read'.



In the above example, relay B has 6 contact units and they are found anywhere in the drawing identified as shown. Each relay, of course, has a different code letter or letters. A typical schematic circuit used in automatic exchanges is included as a matter of interest only, at the end of this Paper (Part 2).

Eyeball Indicators. Some early C.B. switchboards used a D.C. operated indicator known as the eyeball indicator. The D.C. in the calling line operates the indicator directly without a relay. Fig. 35 shows the principle of the eyeball indicator. The 'eyeball' drops as the armature is attracted to the coil end; the subscriber's number is printed on the face of the eyeball.

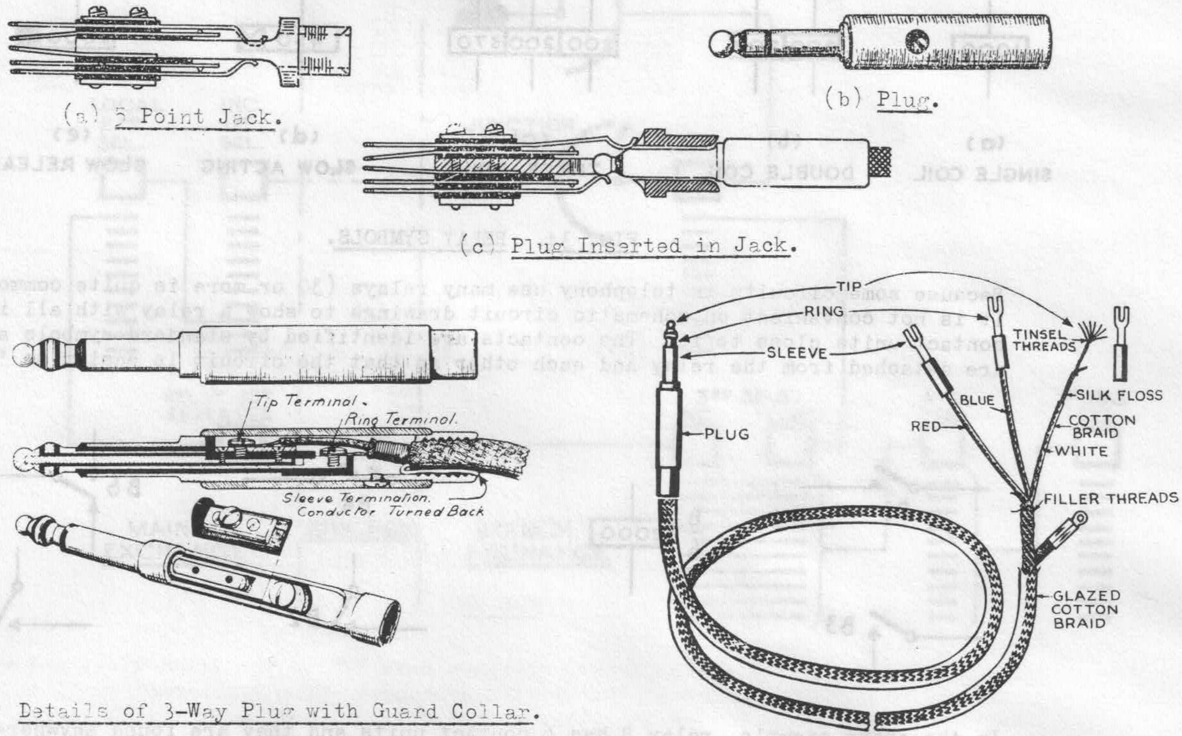


(a) Principle. (b)

FIG. 35. EYEBALL INDICATOR.

Signalling from the exchange to the called subscriber is by means of ringing current. The A.C., to ring the magneto bell in the telephone, is obtained from a hand generator at small exchanges and at larger exchanges from a machine driven generator or a mains operated static device called a sub-cycle ringer, both of which supply all the switchboards at an exchange (hand generators are individual to each board and are usually provided as an alternative should the power ring supply fail).

3.4 Interconnecting between subscribers or between subscribers and trunk or junction lines is generally done by means of plugs and flexible cords which are inserted into special sockets called jacks. Some common types of jacks, plugs and cords are shown in Fig. 36.

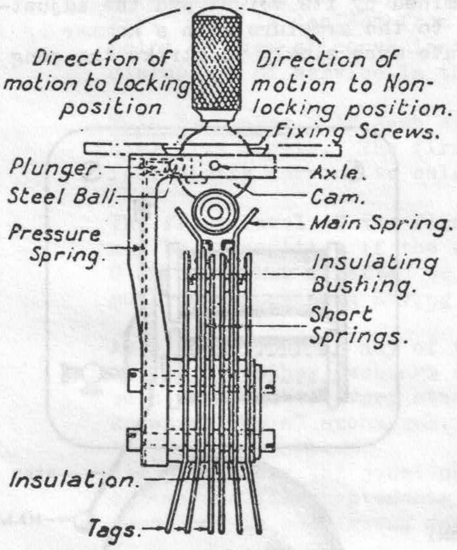


(a) 5 Point Jack. (b) Plug. (c) Plug Inserted in Jack. (d) Details of 3-Way Plug with Guard Collar. (e) Switchboard Cord (3-Way).

FIG. 36. JACKS, PLUGS, CORDS.

Magneto switchboard cords and plugs are generally 2 conductor while C.B. cords and plugs are 3 conductor. They are known as the tip and ring wires or the tip, ring and sleeve wires, respectively. Very often, jacks have auxiliary break springs which make contact with the T and R springs when the plug is withdrawn as in Figs. 36a and 36c.

3.5 Supervision. In order to answer a call from a subscriber or to supervise the progress of a call between two subscribers, the operator connects her own speaking circuit to a particular cord by means of a key. This is just another name for a switch with one 'off' or normal position and one or two 'on' or operated positions. Fig. 37 shows the details of a typical lever key as used on manual switchboards. Another type of key with many miscellaneous applications in telecom is the press type or plunger key.



LEVER KEY.

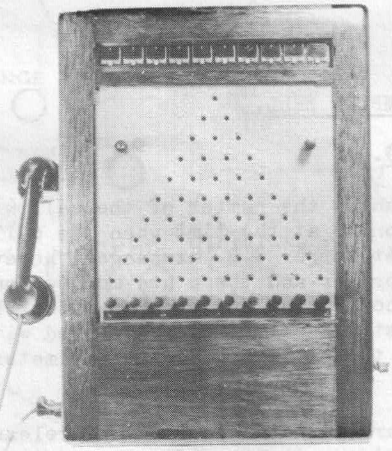
FIG. 37.

The operated positions of keys may be locking, (which means they remain operated without being held) or non-locking, which means they will restore to the normal position when released by the hand.

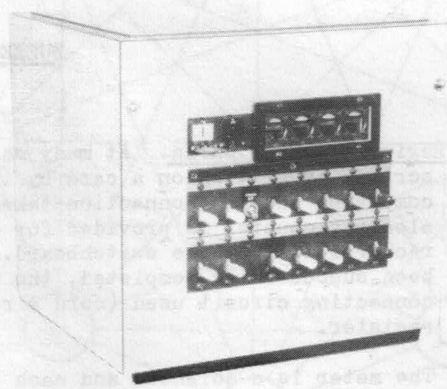
Usually, keys are fitted with many pairs of springs which like relay contacts can be either make, break, change-over or make-before-break, or some combination. Lever keys are sometimes called R and L keys (for ring and listen).

Some small switchboards have no cords and all the interconnecting and supervision is done by means of plugs and jacks or keys only.

Fig. 38 shows two common types of cordless manual switchboards.



(a) Magneto Pyramid Switchboard.



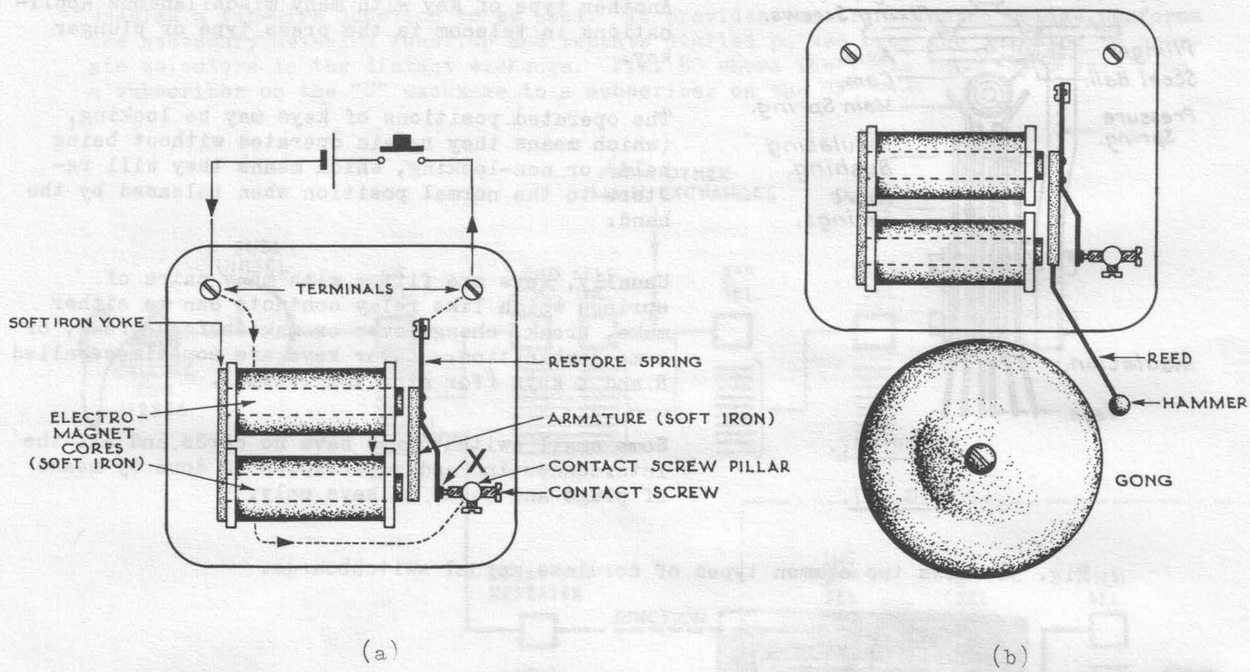
(b) C.B. Cordless Switchboard.

CORDLESS SWITCHBOARDS.

FIG. 38.

3.6 The Audible Alarm or night alarm is obtained by means of a buzzer or trembler bell. These are switched into circuit only when required, usually by a key on the switchboard. Whenever a subscriber calls, the circuit for the alarm is completed via the indicator contacts or a relay. Some intercommunication telephones use buzzers instead of bells in which case the signalling is D.C. and not A.C.

Fig. 39a shows the construction of a buzzer. The magnetism produced by D.C. in the coils attracts the iron armature which, after moving a short distance, opens the contact at X. This stops the current in the coils; the electromagnetism collapses and the armature restores until contact X remakes to recommence the sequence. The armature buzzes at a rate determined by its weight and the adjustment of the contact. If a striker is attached to the armature with a hammer close to a bell gong, the armature will oscillate more slowly to strike the gong on each stroke. This is a trembler bell.



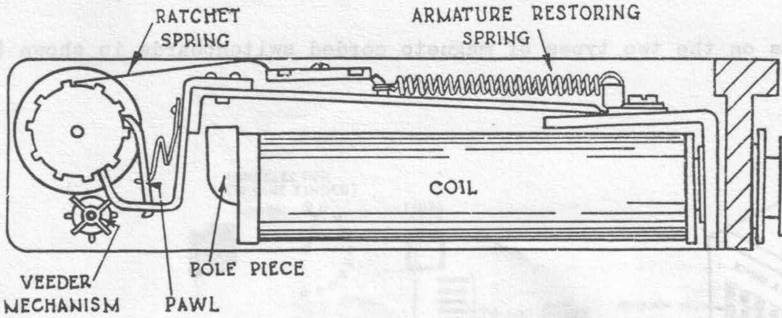
BUZZER AND TREMBLER BELL.

FIG. 39.

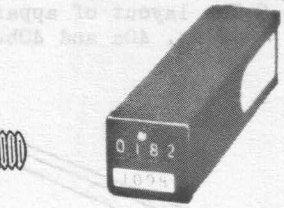
3.7 Registration of Calls. At many manual exchanges the number of the calling subscriber is written on a card by the telephonist at the time when the call is completed and the connection taken down. At larger C.B. exchanges, however, an electric counter is provided for each subscriber and these are mounted on a rack remote from the switchboard. When a connection between two subscribers has been successfully completed, the telephonist presses a key associated with the connecting circuit used (cord circuit) and the call is added to the meter or register.

The meter is a solenoid and each time the armature is operated and released, a ratchet moves a units counting wheel forward one digit. After every ten unit calls, the tens wheel is moved forward one figure, and so on for the hundreds wheel and the thousands wheel in the same manner as the mileometer of a car. Fig. 40 shows a typical meter and its construction.

Meters are used also in all automatic exchanges, the type shown below being the most common.



(a) Internal Construction.

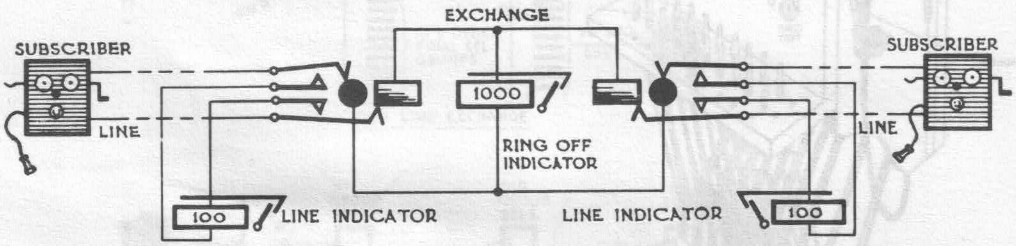


(b) Complete with Cover.

SUBSCRIBERS' METER OR REGISTER.

FIG. 40.

3.8 Basic Magneto Switchboard. The basic principle of connecting two magneto telephones together by means of a cord circuit is shown in Fig. 41.



BASIC MAGNETO EXCHANGE.

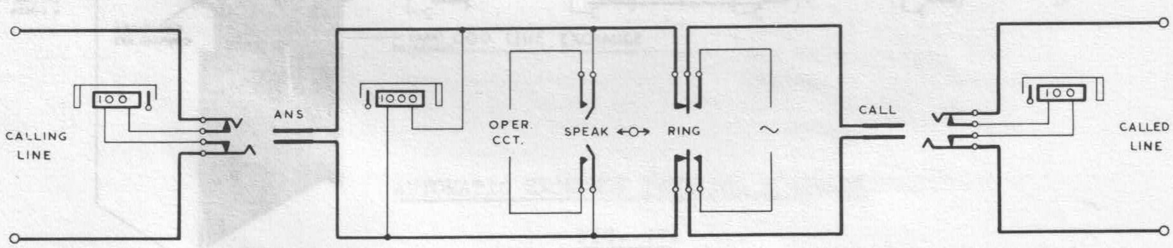
FIG. 41.

To set up this connection, however, the operator must be able to –

(i) Connect the operator's telephone to any cord circuit to speak to the caller and ascertain the required number, or to supervise the progress of the call once it is set up.

(ii) Connect the hand generator or power ringing current to the calling cord to ring the wanted subscriber.

This is done by means of a key (R and L) for each cord circuit which, without altering the basic through connection is connected as shown in the simplified schematic circuit of Fig. 42.

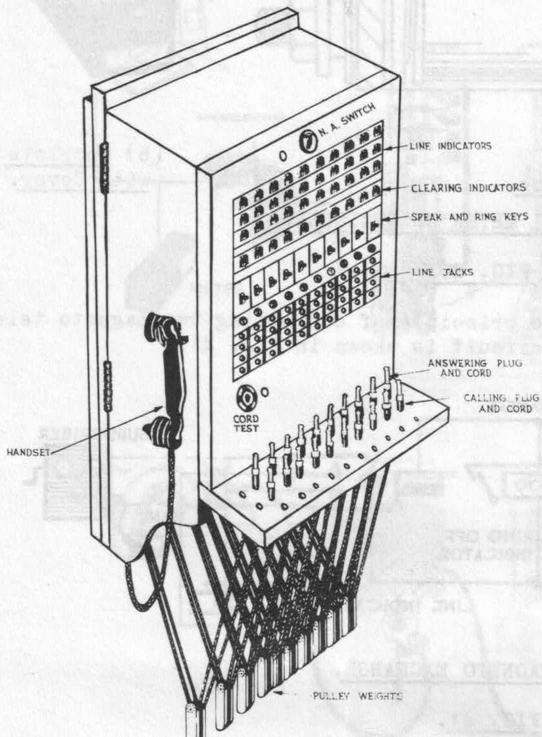


SIMPLIFIED MAGNETO SWITCHBOARD CIRCUIT.

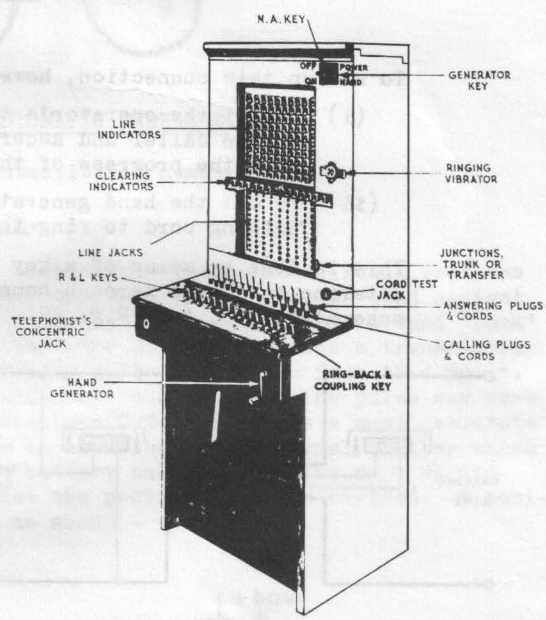
FIG. 42.

The clearing indicator has no appreciable shunting effect on the conversation as it offers a very high impedance to A.C. at speech frequencies.

3.9 The layout of apparatus on the two types of magneto corded switchboards is shown in Figs. 40a and 40b.



(a) Wall Pattern.

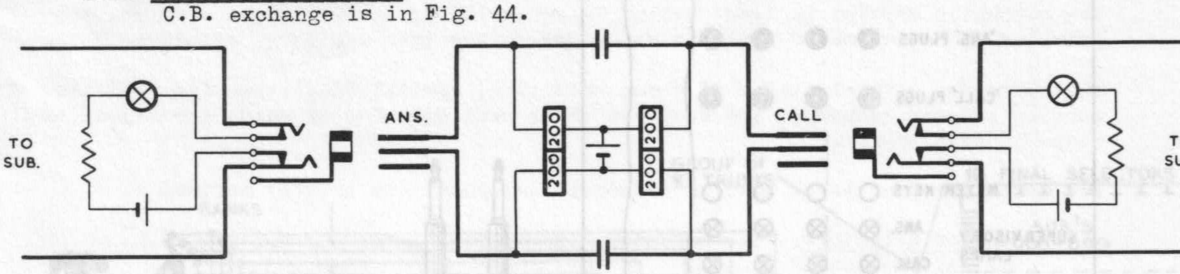


(b) Floor Pattern.

CORDED MAGNETO SWITCHBOARDS.

FIG. 43.

3.10 Basic C.B. Exchange. The basic subscribers line and cord circuits of one type of C.B. exchange is in Fig. 44.

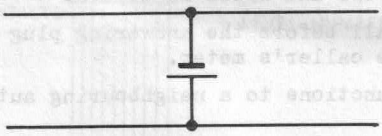


BASIC C.B. CONNECTION.

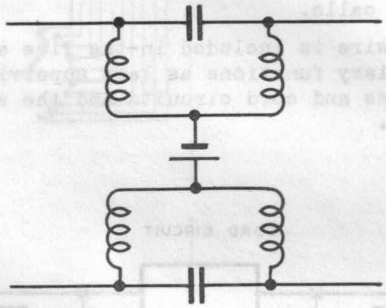
FIG. 44.

The current for the transmitters of both telephones is fed from the central battery via a transmission feeding bridge which is a part of the cord circuit. There are several types of transmission feeding bridge but the earlier types have largely been superseded by the type shown above.

3.11 Transmission feeding bridges are a vital part of C.B. telephony for two main reasons:-



(a)



(b)

FIG. 45.

The arrangements of Fig. 45a would not work because the low impedance of the battery would short circuit all A.C. speech signals from both telephones. Also all lines using the same central battery would be connected together.

The speech currents must pass freely between the two lines connected and all circuits using the same battery must be isolated from the battery for everything except D.C., so that crosstalk between circuits cannot be caused by the common supply. This can be accomplished by supplying each side of circuits to be connected via a pair of inductance coils or retards which offer a very high impedance to A.C. at speech frequencies while the resistance to D.C. is relatively low (see Fig. 45b). The A.C. speech currents pass from one side to the other via the two capacitors. This is the same arrangement as shown in Fig. 44 where the retards consist of two double winding relays, the contacts of which in modern C.B. cord circuits are used for supervisory purposes.

3.12 The cord circuits of a C.B. exchange, include facilities for speaking and ringing and these are provided by means of a key or keys as already described for magneto cord circuits. In addition, individual supervision is provided for each answering and calling cord by means of lamps. The key and cord shelf of a typical C.B. switchboard having 16 cord circuits is arranged as shown in Fig. 46.

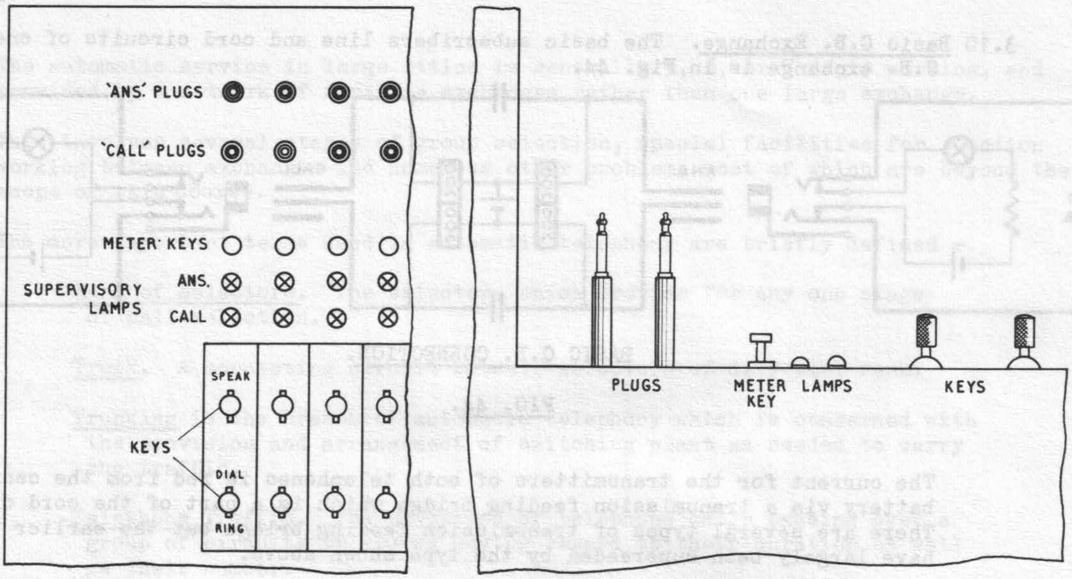


FIG. 46. TYPICAL SHELF LAYOUT C.B. EXCHANGE.

The supervisory lamps are extinguished while the call is in progress but the answering supervisory lamp glows when the caller hangs up; the calling supervisory lamp glows until the called party answers and after he clears.

The meter key is pressed at the end of the call before the answering plug is withdrawn and this adds one to the reading of the caller's meter.

The dial key is used when the exchange has junctions to a neighbouring automatic exchange or R.A.X.

3.13 The subscriber's line circuit shown in Fig. 44 is only used with some private branch exchange switchboards (P.B.Xs.). C.B. public exchanges use relays in the line circuit, the circuit for the line lamp being completed by a relay contact instead of by way of the telephone directly. Each line circuit also includes the subscriber's meter for registering the local calls.

3.14 Sleeve Wire. A third wire called the sleeve wire is included in the line and cord circuits to provide a circuit for such auxiliary functions as lamp supervision and metering. The basic functions of the line and cord circuits and the sleeve wire are summarised in block form in Fig. 47.

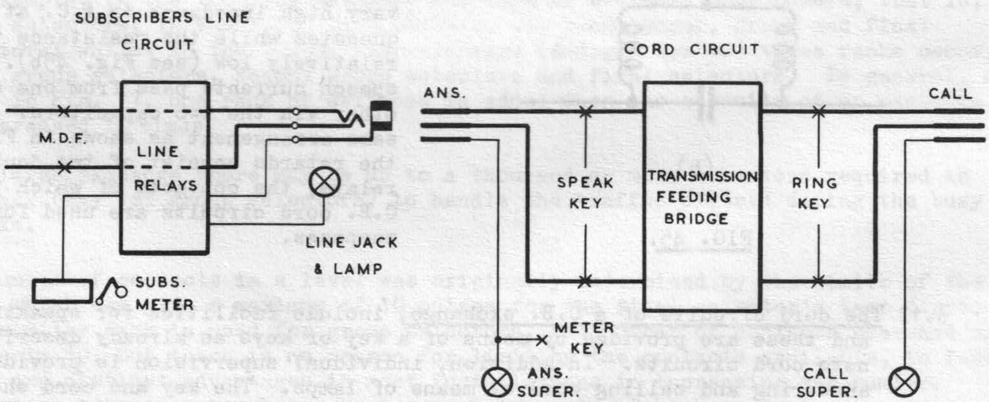


FIG. 47. BASIC C.B. EXCHANGE FUNCTIONS.

4. MANUAL EXCHANGES.

4.1 Manual exchanges vary in size from small offices with one trunk line and one subscriber to those having a large number of trunk and junction lines and several thousand subscribers.

In all large exchanges, the trunk and junction lines are connected to switchboards separate from the subscribers. The exchange is referred to as consisting of a number of 'positions' rather than switchboards as they are mounted together without side panels. The subscribers' lines terminate on the local or 'A' positions and the trunks and junctions on the 'Tk' or 'B' positions.

A telephonist in a large exchange can only use the cord circuits to connect to jacks on the same position and the two adjoining positions. In order that any two of all the subscribers and trunk or junction lines may be interconnected, exchanges with more than two operating positions require special provisions in addition to the basic line and connecting circuits already described.

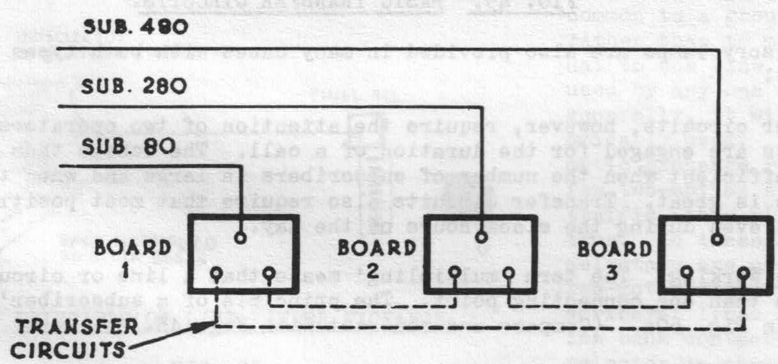
There are two methods of providing the facility and therefore two distinct methods of operating in large manual exchanges. These are -

Transfer working.

Multiple working.

4.2 Transfer Working. With transfer working (see Fig. 48), transfer jacks and associated circuits are installed on each switchboard.

Suppose that at a magneto exchange of three 200-line boards, a subscriber on board 1 calls and asks for subscriber 280, the telephonist can reach across and plug into the jack 280. If, however, the subscriber asks for 480, the telephonist plugs into a disengaged transfer circuit and informs the telephonist on the 401-600 board, who then plugs into the appropriate transfer jack on her own position and completes the call to subscriber No. 480.

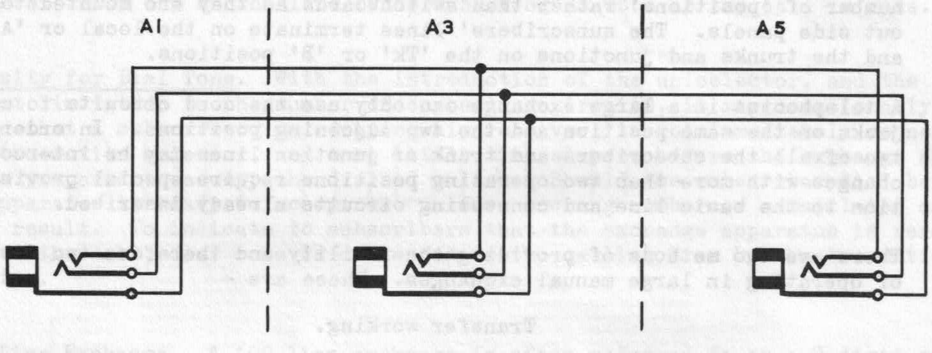


PRINCIPLE OF TRANSFER CIRCUITS.

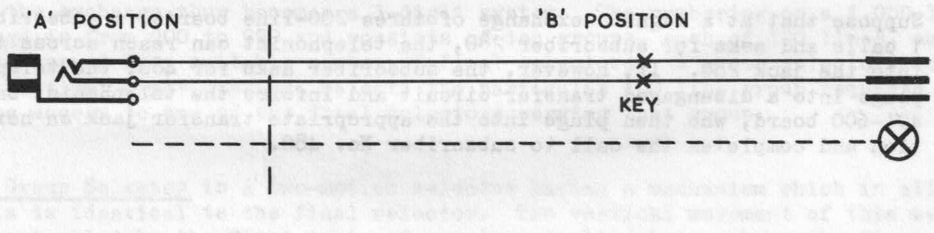
FIG. 48.

When the number of positions makes it difficult to pass the requirements easily by one telephonist speaking normally to another, then there is associated with the transfer circuits a series of "order wires" terminating on each position. The telephonist desiring to transfer a call communicates with the wanted telephonist by means of the appropriate order wire. These order wires are only for speaking between telephonists and are not used for traffic. (See later.)

Transfer circuits may be either 'jack ended' or 'plug ended' (See Fig. 49).



(a) Jack ended.



(b) Plug ended.

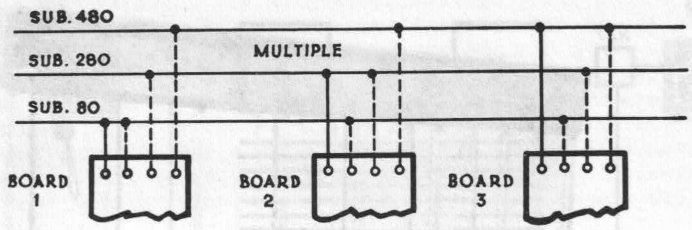
FIG. 49. BASIC TRANSFER CIRCUITS.

Supervisory lamps are also provided in many cases with both types of transfer circuit.

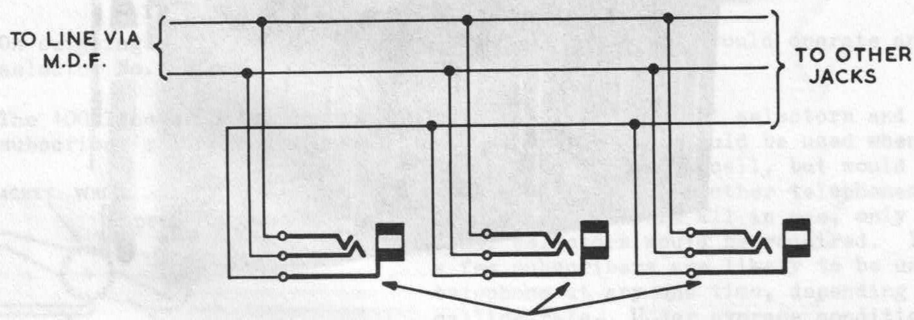
Transfer circuits, however, require the attention of two operators, and two cord circuits are engaged for the duration of a call. The scheme thus becomes slow and inefficient when the number of subscribers is large and when the volume of traffic is great. Transfer circuits also require that most positions shall be staffed even during the slack hours of the day.

4.3 Multiple Working. The term 'multipling' means that a line or circuit terminates on more than one connecting point. The principle of a subscriber's multiple is shown in Fig. 50a. (Compare and contrast with Fig. 48.)

The jacks have 'appearances' at frequent intervals along the row of positions. In practice, the 'jack field' of multiple boards is divided into panels and there may be two panels per position or seven panels in three positions. A multiple appearance every three positions (and one unstaffed or dummy position at each end) allows every operator access to every line. Fig. 51 shows the typical assembly of a magneto multiple switchboard and Fig. 52 shows the carcass of three positions of a modern C.B. multiple exchange. Note the seven panels for jacks and lamps and the way the positions are fitted together without side panels to facilitate the multiple cabling.

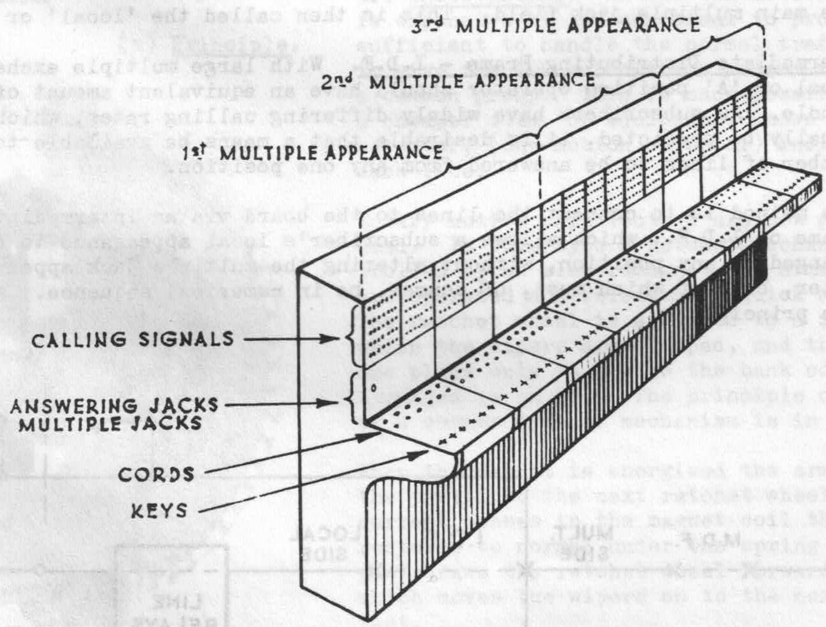


(a) Principle of Multiple.



(b) Multiple Jack Wiring.

FIG. 50.



TYPICAL ASSEMBLY MAGNETO MULTIPLE SWITCHBOARD.

FIG. 51.

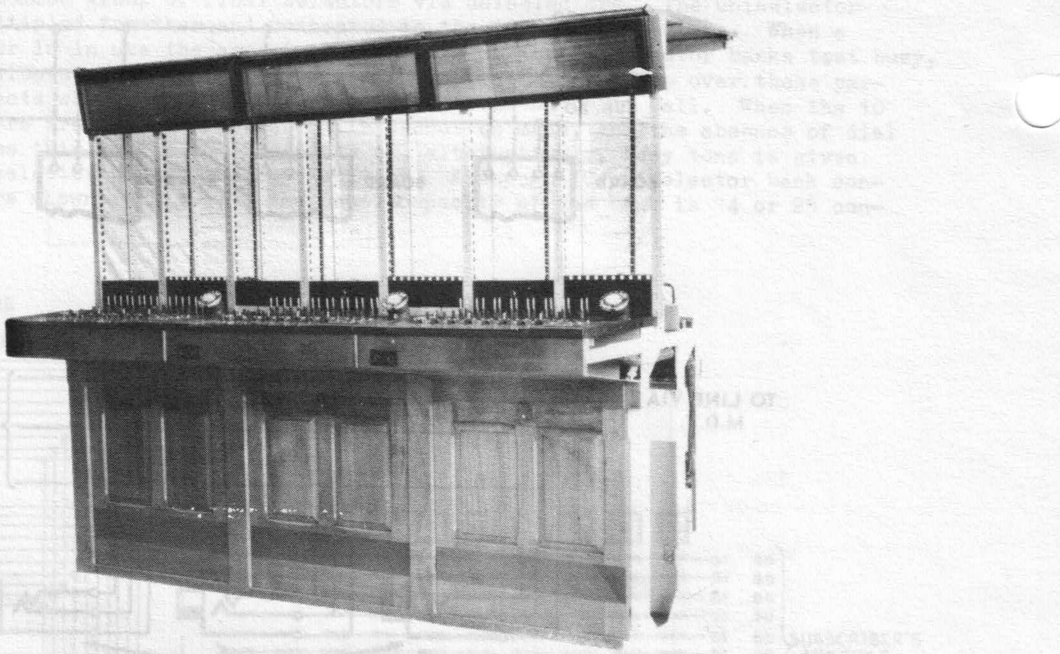


FIG. 52. C.B. MULTIPLE POSITIONS (BEFORE INSTALLATION).

The line indicators or lamps for any one line appear on one position only and in some cases an appearance of the line jack on this position is made separate from the main multiple jack field. This is then called the 'local' or 'home' jack.

4.4 Intermediate Distributing Frame - I.D.F. With large multiple exchanges, each local or 'A' position operator should have an equivalent amount of traffic to handle. As subscribers have widely differing calling rates, which cannot usually be predicted, it is desirable that a means be available to alter the number of lines to be answered from any one position.

One method is to connect the lines to the board via an intermediate distributing frame or I.D.F., which allows a subscriber's local appearance to be readily changed to any position, without altering the multiple jack appearances or the meter, both of which must, of course, be in numerical sequence. Fig. 53 shows the principle.

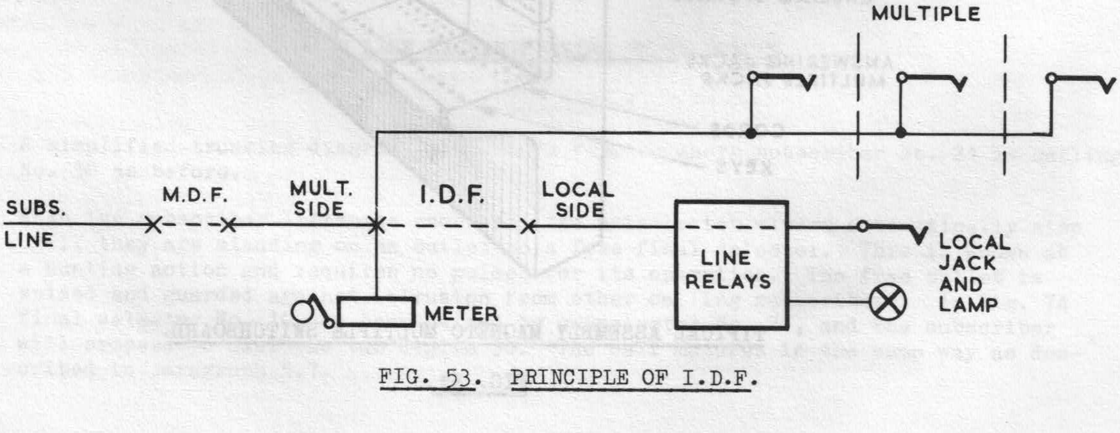


FIG. 53. PRINCIPLE OF I.D.F.

The I.D.F. consists of two sets of terminal blocks, one set for the multiple side and another for the local side. By the simple process of changing a few jumpers the local jacks and lamps of high and low calling rate subscribers can be distributed evenly over all positions.

Note: Magneto multiple exchanges having meters, electrically 'self' restoring indicators, and full I.D.F. facilities have been installed, but very few are still in service. For a number of years now, all new multiple exchanges have been C.B., as a C.B. area is more readily converted to automatic working.

4.5 Modern practice, however, with C.B. multiple exchanges, is to have no separate local jack. The local lamps appear below the multiple jack field on the same panel for a particular subscriber, as one of the multiple jack appearances. It is now considered that the complication of a separate local jack is not warranted. A double sided I.D.F. is not required to distribute the traffic, but a single set of blocks is still required to serve as a connection point. Fig. 54 shows the principle now used.

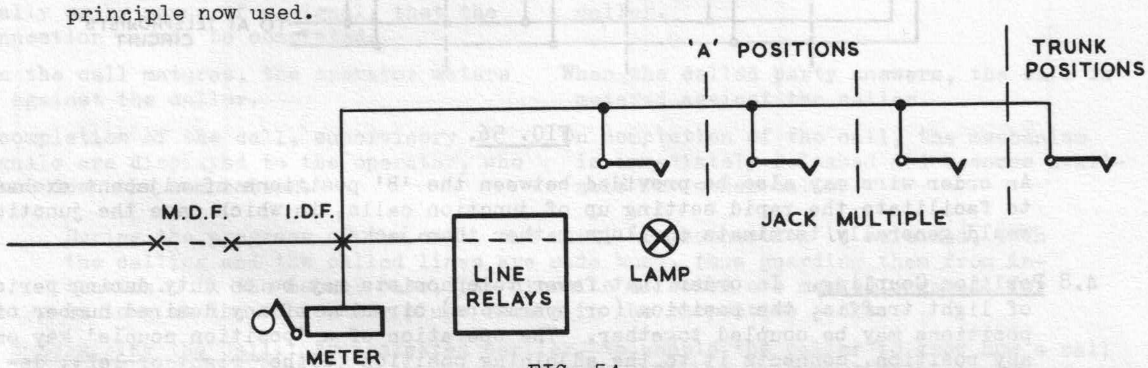
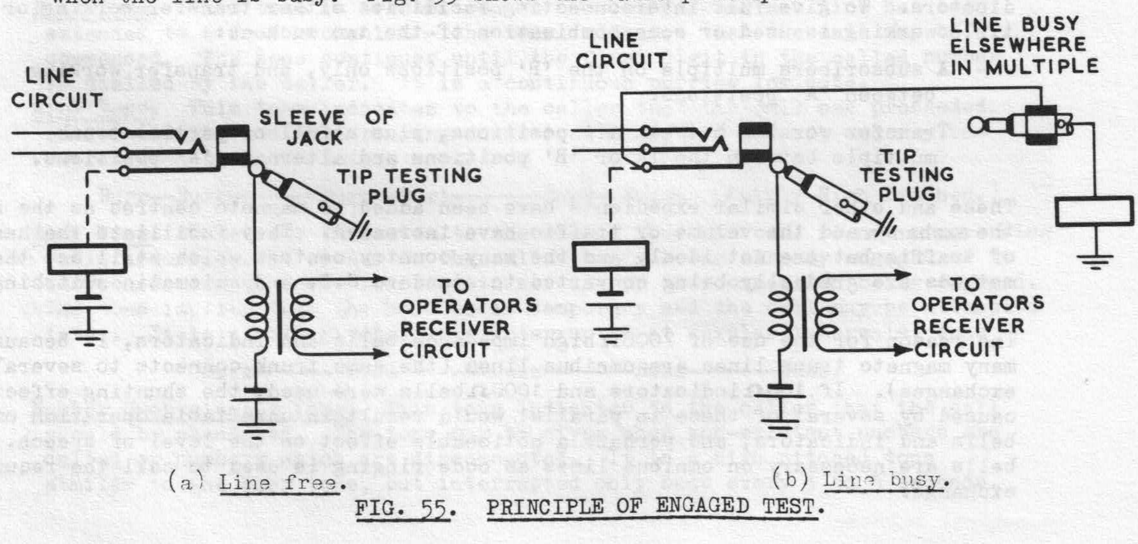


FIG. 54.

4.6 Engaged Test. Multiple exchanges have in effect one bothway jack, and several out-going jacks for each line. To avoid attempts to connect calls to jacks which may be engaged at another appearance elsewhere along the multiple, it is necessary that the telephonist have a way of finding out if a line is free or engaged before plugging into the jack to call. To test the line the telephonist touches the tip of the calling plug on the barrel or sleeve of the jack, and if the line is busy a click is heard in the head receiver and if the line is free there is no sound. The circuits are so arranged that the sleeve of the jack and tip of the plug are at the same potential when a line is free, but have a difference of a few volts when the line is busy. Fig. 55 shows the basic principle.



(a) Line free. (b) Line busy.

FIG. 55. PRINCIPLE OF ENGAGED TEST.

4.7 Order Wires. To facilitate traffic handling in large manual exchanges, each position is provided with a set of press type keys to enable direct communication between telephonists. As already mentioned, this is essential where there are several positions using transfer working, but it is also very useful in multiple exchanges, where it is often provided. Fig. 56 shows the basic circuit, such as required to give, for example, positions A5, A6, A7, A8, direct access to, say, position A1. For 10 positions there would be 10 such order wires.

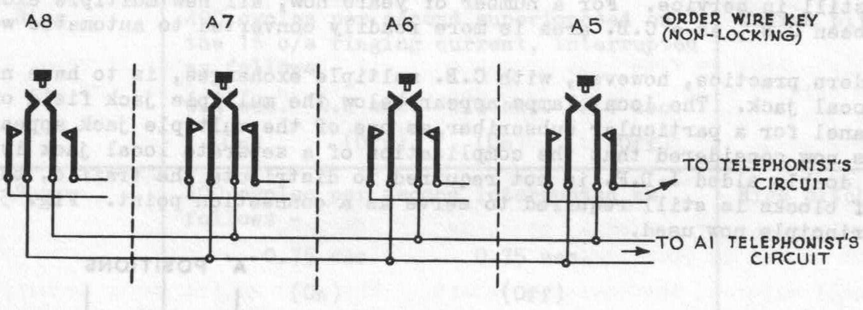


FIG. 56.

An order wire may also be provided between the 'B' positions of adjacent exchanges to facilitate the rapid setting up of junction calls, in which case the junctions would generally terminate on plugs rather than jacks.

4.8 Position Coupling. In order that fewer telephonists may be on duty during periods of light traffic, the position (or operators) circuits of any desired number of positions may be coupled together. The operation of a 'position couple' key on any position, connects it to the adjoining position (either right or left, depending on the exchange). This allows the cord circuits of all coupled positions to be used with the operators set plugged into any one of the positions.

4.9 Magneto Trunk Working. At small country exchanges having only one switchboard (using the equipment shown in Fig. 40 and in many cases the smaller cordless boards) the trunk lines have 2000Ω bells rather than indicators. This is satisfactory for no more than about three or four lines, each bell being given a distinctive tone. The trunk line jacks appear on the same jack field as the subscribers line jacks but the bell is not usually disconnected by the jack springs when a plug is inserted.

At larger centres separate trunk switchboards are used which have 2000Ω line indicators. To give full interconnecting facilities either transfer working or multiple working is used or some combination of the two such as:

- A subscribers multiple on the 'B' positions only, and transfer working between 'A' positions.

- Transfer working between all positions, plus a full or partial trunk multiple between the Tk or 'B' positions and alternate 'A' positions.

These and other similar expedients have been added to magneto centres as the size of the exchange and the volume of traffic have increased. They facilitate the handling of traffic but are not ideal, and the many country centres which still use these methods are gradually being converted to standard C.B. and automatic switching.

The reason for the use of 2000Ω high impedance bells and indicators, is because many magneto trunk lines are omnibus lines (the same trunk connects to several exchanges). If 100Ω indicators and 1000Ω bells were used, the shunting effect caused by several of these in parallel would result in unreliable operation of the bells and indicators, and perhaps a noticeable effect on the level of speech. The bells are necessary on omnibus lines as code ringing is used to call the required exchange.

4.10 There are two standard types of C.B. exchange -

(i) A multiple exchange to cater for up to 2000 subscribers. Separate local and trunk positions are provided; the trunk positions are of the 'sleeve control' type.

(ii) A non-multiple exchange using combined 'A' and trunk positions having a maximum capacity of 200 subscribers and 18 trunk lines (usually for 2 positions; maximum 3).

These exchanges are generally known as C.B. country exchanges as they were designed for service outside metropolitan areas, and facilities for long lines and party lines are readily included if necessary.

4.11 C.B. Multiple Exchanges. Fig. 57 shows a modern C.B. multiple exchange with 5 local and 12 trunk positions, using positions as in Fig. 52.

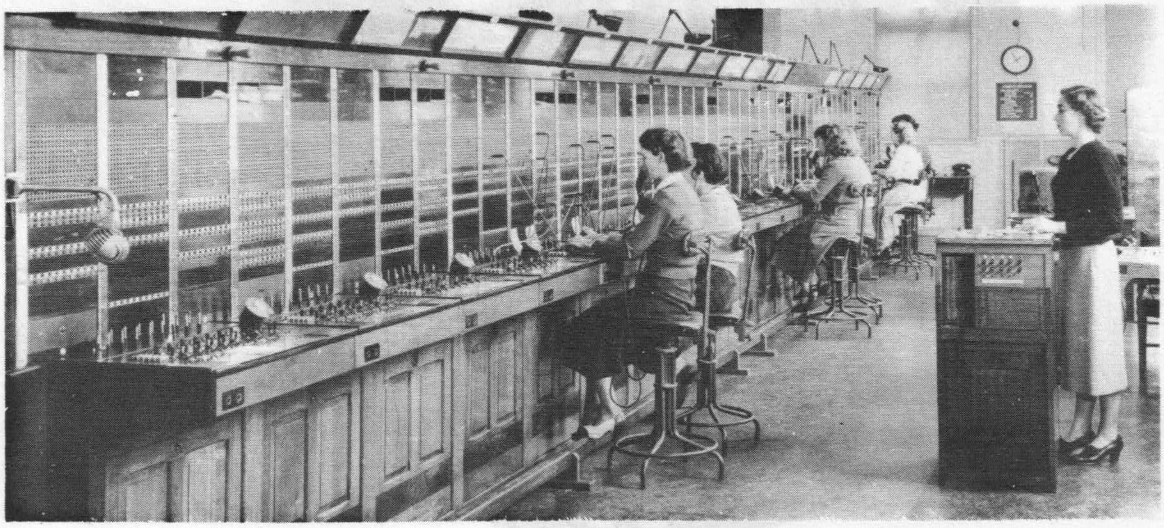


FIG. 57. C.B. MULTIPLE EXCHANGE.

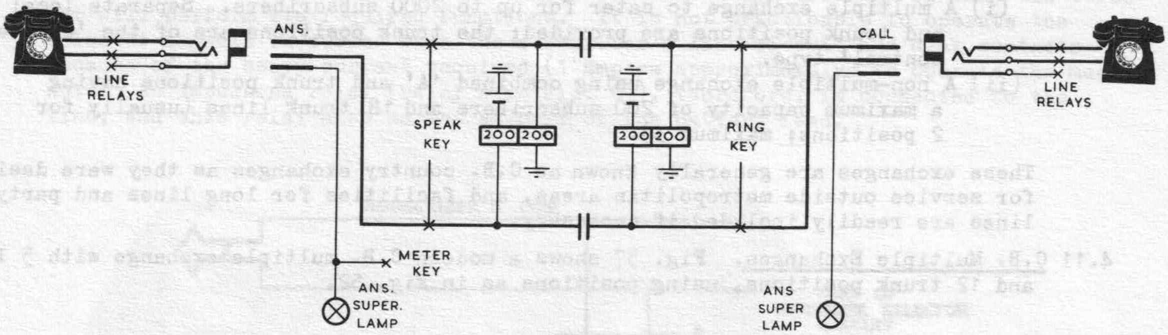
The A Positions have line and cord circuits which function as described in Section 3. The subscribers lines make a multiple appearance every 5 panels - 7 panels extending over 3 positions.

Trunk Positions. When first introduced in 1948 each exchange of this type was equipped with two types of trunk position:

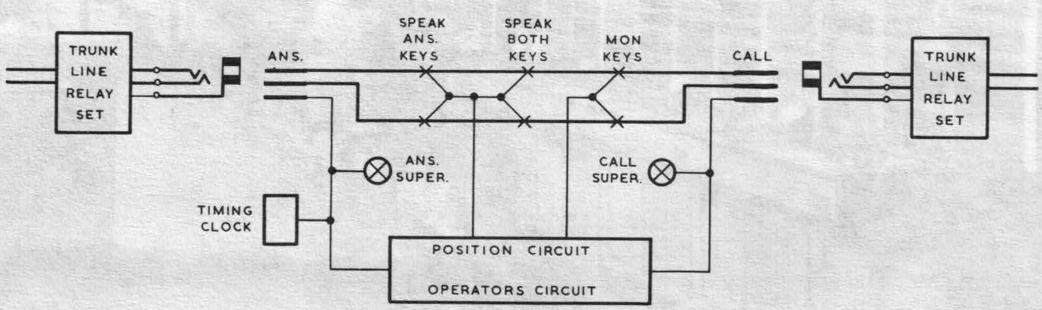
- Terminating trunk position used for switching subscriber to trunk, and trunk to subscriber calls. (The call 'terminates' on a local subscriber).
- Through trunk position used for switching trunks to trunks.

Sleeve Control. The reason for the two distinct switching facilities of the trunk positions is that the cords used for plugging into trunk line jacks operate on the 'sleeve control' principle and those for connecting to subscribers' jacks operate on the same principle as the 'A' position cord circuits. The trunk positions are known, therefore, as sleeve control trunk positions. This term distinguishes trunk cord circuits and line circuits from those used on the C.B. local 'A' positions which, for want of a better term, are called 'bridge control' (the supervisory relays in the transmission feed are bridged across the cord circuit T and R conductors).

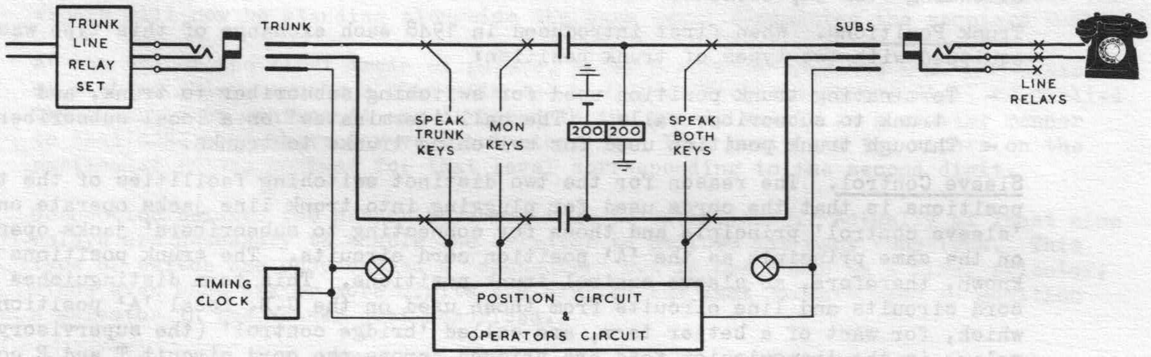
With sleeve control the actual Through cord circuit is reduced to its simplest elements (tip to tip and ring to ring) while most of the signalling and supervisory functions are performed in the trunk line circuit, some of these functions being controlled via the sleeve wire. Fig. 58 compares and contrasts the basic elements of the three types of connection required at a C.B. multiple exchange with sleeve control trunk positions.



(a) 'A' position cord circuit (bridge control).



(b) Through position cord circuit.



(c) Terminating position cord circuit.

FIG. 58.

It may at first seem an unnecessary complication to have special cord circuits for trunk working, but this is actually not so. The types of trunk and junction lines (or channels) which terminate on large country manual exchanges (and metropolitan manual trunk exchanges) are many and varied, but briefly they are:

Generator signalling trunks.
Auto dialling or D.C. signalling trunks.
Voice frequency and 2 V.F. signalling trunks.

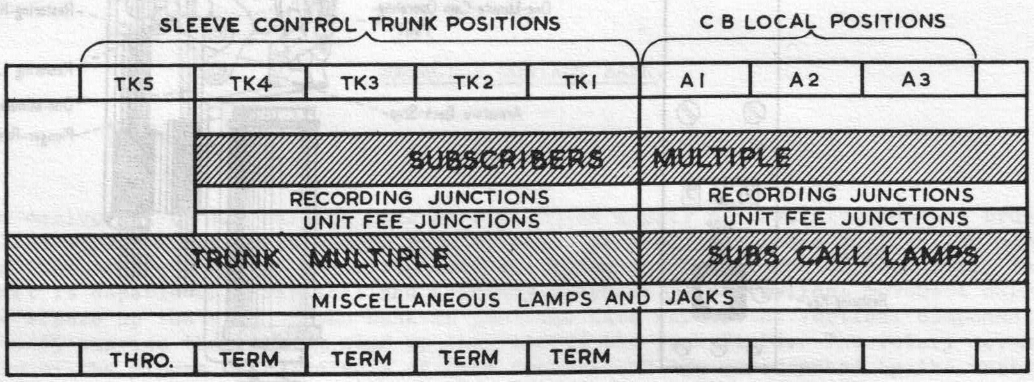
If all types of trunks were connected direct to the jacks as do subscribers' lines, it would only be possible to interconnect them with the subscribers and each other by numerous special cord circuits and several different operating procedures. Therefore, each line terminates on a circuit containing signalling and terminating facilities suitable for that particular trunk, but controlled from a standard cord and position circuit. (Fig. 58b.)

The Terminating cord circuits have one sleeve control cord for connecting to the trunk jacks and one bridge control cord for the subscribers. (Fig. 58c.)

In order to facilitate traffic handling during periods of very light traffic (for example 11 p.m. to 7 a.m. when there may be only one telephonist on duty) it was common practice to equip the first Terminating position with 2 or 4 Through cord circuits and a 'Composite' position circuit.

Trunk Multiple. The trunk jacks are multipled on all the trunk positions, and the subscribers' jacks on both the local positions and the Terminating and/or Composite trunk positions. On Through trunk positions, the trunk jacks only are multipled. The trunk appearances occur every five or four panels. Fig. 59 shows a typical layout of lines over a number of local and trunk positions.

In such an exchange Tk 1 position would generally have 2 or 4 Through cord circuits as mentioned above. It may then be called a Composite position.



TYPICAL LAYOUT, MULTIPLE EXCHANGE JACK AND LAMP FIELD.

FIG. 59.

Recording Junctions are a type of transfer circuit used in these exchanges and are provided between the A positions and the Terminating (or Composite) positions. Their purpose is to extend calling subscribers who desire trunk service direct to the Terminating position operator, who records the details of the call on a docket. Having obtained the caller's number the trunk operator 'overplugs' on the multiple to connect to the caller (if the call is completed on demand), or calls back via the subscriber's multiple jack (if the call matures after a delay). In either case, the recording junction is released so that the connection is made via one cord circuit only. Recording junctions are jack ended on both A and Tk positions.

Call timing at these exchanges is by means of B.P.O. clock No. 44 (Fig. 60). Each terminating trunk switchboard is equipped with four clocks, one for every second cord circuit. These work in conjunction with the cord circuit and time check circuit to:

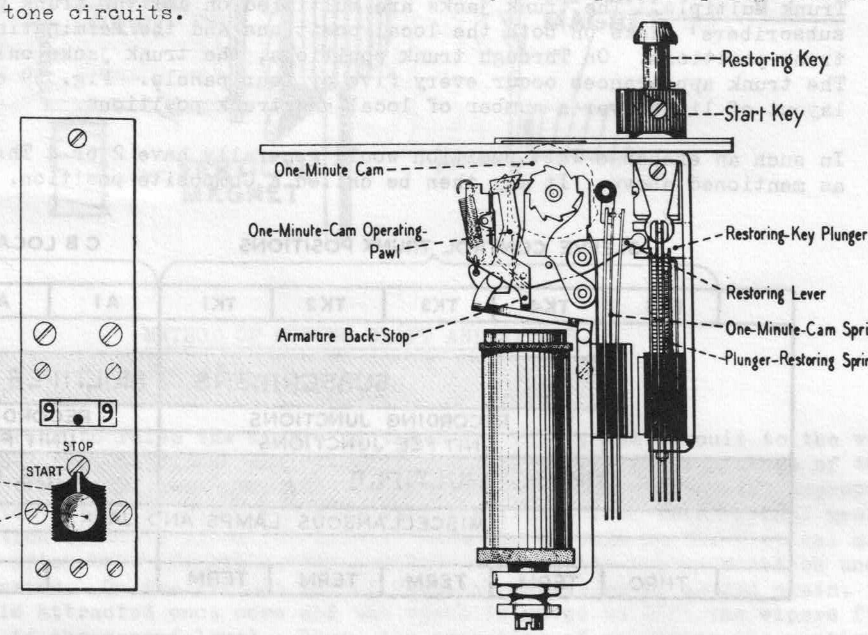
- Indicate to the operator on two numbered discs the duration of the call in minutes and tenths of a minute. (The operator starts the clock by hand when conversation between parties connected to the associated cord circuit has commenced.)

- At 2.8, 5.8 and 8.8 minutes after the start, cause the associated meter lamp to light and then to go out again at 3, 6 and 9 minutes respectively. When the calling line clears the clock stops automatically and indicates the total time of the call, until reset manually by the operator to read 9.9. (The first pulse brings the clock to 0.0).

- Connect pip tones to the circuit (if provided) at 2.8, 5.8 and 8.8 minutes to notify the parties that a further 3 minute period will start in 12 seconds. The 'pip tones' are 3 pips of 900 c/s tone at 1 second intervals.

- Cause the meter lamp to flicker if allowed to time up to 9.9 minutes. It should be reset to zero if the call exceeds 9 minutes.

The clock works on the principle of the meter or register. The operating solenoid responds to 6 second (1/10 minute pulses) and auxiliary cams operate spring-sets for the lamp and pip tone circuits.



(a) Top View.   (b) Side view of mechanism.

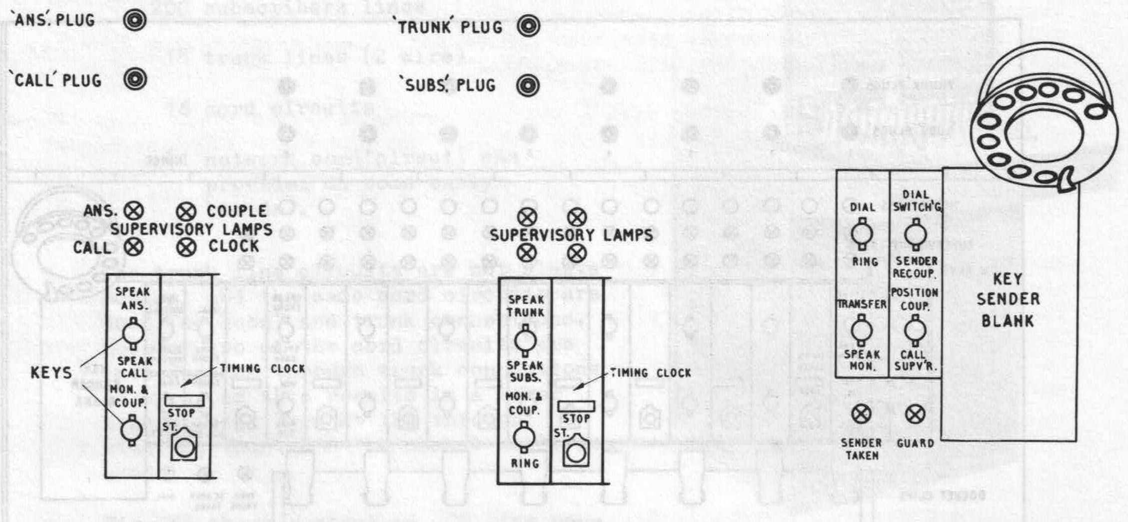
FIG. 60. B.P.O. TIMING CLOCK.

Four Wire Switching. The terminal equipment of certain trunk lines is such that certain transmission advantages are possible on through trunk calls if the trunks are connected together by 2 sets of cords instead of one pair only. The Through positions may be provided with the extra pairs of cords which are called 'network' cords and the particular lines are provided with a 'net' jack above the normal line jack.

The circuit will work when switched via the normal jacks and cords only, but when both trunks are equipped with network jacks, the net cords should be used also, as this results in a through connection with a much lower transmission loss.

4.12 Important Changes in Trunk Operating. In 1955 and 1958 there were two significant amendments to trunk positions which altered the appearance of the key shelf and also completely changed the operating procedure.

Originally the keys of Through and Terminating Positions were arranged as shown (for one of the eight cord circuits only) in Figs. 61a and 61b; the position circuit keys common to all cord circuits were as in Fig. 61c.



(a) Cord Circuit. Through Position.

(b) Cord Circuit. Terminating Position.

(c) Position Circuit. Through and Terminating Positions.

FIG. 61. EARLY TRUNK POSITIONS.

In this case, operation of the speak key to either 'Ans' or 'Call' 'divides' the answer and call sides of the cord circuit and it remains divided even if the key is restored to normal. Momentary operation of the 'Monitor and couple' key is necessary before the parties can converse. The couple lamp glows while the cord circuit is divided. The functions of the position circuit keys - 'Dial','Ring' and 'Transfer' - become effective through whichever 'Speak' key is operated, and the 'Speak Mon' key allows the operator to speak to both parties via a monitor key.

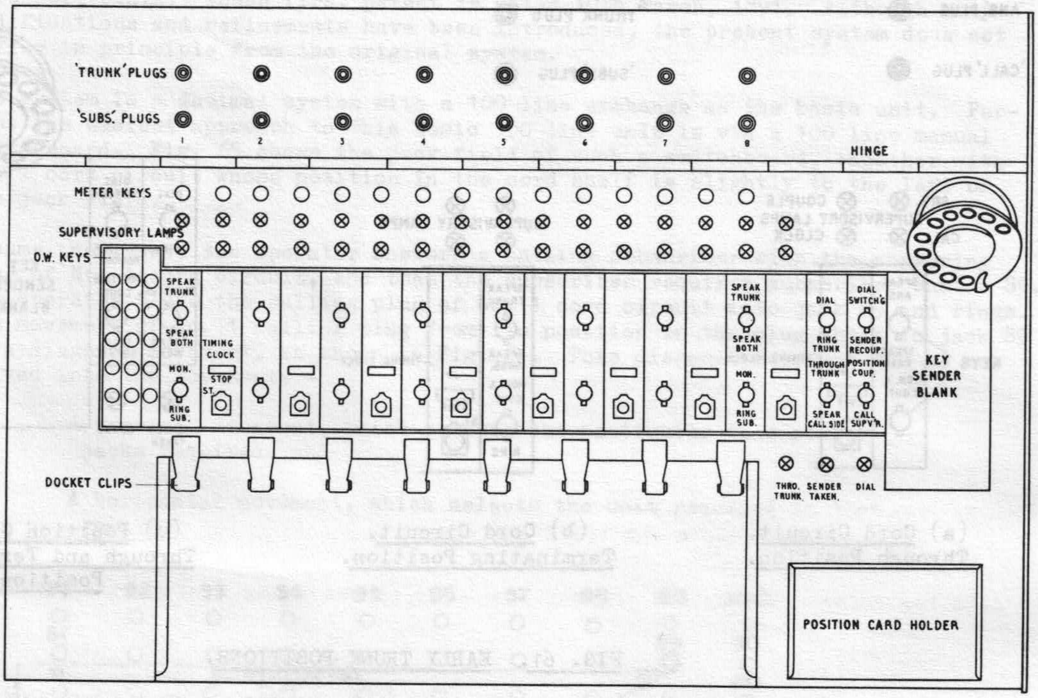
All incoming trunk calls were answered on the Terminating positions and if found to be a 'through' connection were transferred to light the call lamp on the Through position by momentary operation of the 'Transfer' key.

In 1955 the cord circuit and key functions were altered to include an operating feature known as 'caller in circuit'. In this case, the circuit is not divided by the speak keys, and the 'Speak Call' and 'Speak Subs' keys (Figs. 61a and 61b) have been changed to 'Speak Both'. This leaves the 'caller in circuit' to hear the progress of his call. The 'Speak Mon' key (Fig. 61c) was changed to 'Speak Call Side' to allow the caller to be cut off during setting up of the call if this is necessary when the 'Speak Both' key is operated. At the same time the position and operator's circuits were amended to provide a facility known as 'overlapping', whereby the telephonist may listen across one connection (Mon key) whilst establishing another (via speak keys), without speech on either connection being audible to a subscriber on the other.

These facilities were retained when the new Composite cord circuit was introduced in 1958, so the functions of the Speak and Mon keys, are the same as for the latest circuit, the key arrangements for which are shown in Fig. 62.

The first Composite positions to be installed used separate Through and Terminating cord circuits (Figs. 58b and 58c) together with a suitable position circuit.

A Composite cord circuit has now been developed which may, by the operation of a key, be changed as required to switch either through or terminating calls. After 1958 all trunk positions installed will use these cord circuits and separate Through and Terminating positions will be no longer necessary. Fig. 62 shows the key shelf layout of a trunk position having the new Composite cord circuits.



COMPOSITE TERMINATING/THROUGH TRUNK POSITION - KEY SHELF.

FIG. 62.

The Composite cord circuits function as a Terminating connection normally, but may by changed to a Through circuit for the duration of the call, by momentary operation of the 'Through Trunk' position key when the particular 'Speak Both' key is operated.

The other position circuit keys are unchanged. The 'Dial' and 'Dial switching' connect the dial circuit to whichever cord has the speak key operated. The 'Ring trunk' key transmits a suitable signal (+ battery) to the trunk line circuit via the relevant cord circuit.

Meter keys may be added to these trunk positions when it is desired to have the trunk operator charge directly for 'short haul' trunk calls (2 or 3 unit fees), by pressing the meter key the required number of times every 3 minutes, instead of preparing a docket.

Key senders may be provided in the future at busy centres, and in lieu of dialling the number may be 'keyed' on ten (press type) keys. The 'Dial' key alone connects the sender into circuit.

Network cords and jacks are not now provided as it was found that telephonists generally fail to make use of the four wire switching facility.

4.13 C.B. Non-Multiple Exchanges. If there are insufficient subscribers to warrant the installation of multiple positions, one or two non-multiple boards (maximum three) may be used. The standard C.B. non-multiple combined A and trunk position is equipped for a maximum of:

200 subscribers lines

18 trunk lines (2 wire)

16 cord circuits

(1 network cord circuit was provided on some early boards).

The trunk line circuits are not sleeve control and the same cord circuits are used for local and trunk connections. However two of the cord circuits are intended for through trunk connections (2 wire) as this results in a lower transmission loss at the through station, than when the normal cords are used.

Fig. 63 shows a standard 200 line non-multiple combined A and trunk position.

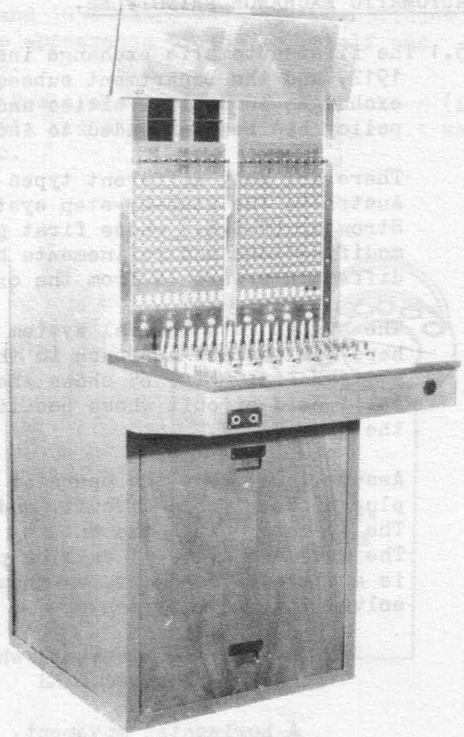


FIG. 63.

4.14 For reference purposes the various types of switching equipment for manual exchanges are listed below -

PUBLIC MANUAL EXCHANGES		PRIVATE MANUAL BRANCH EXCHANGES	
Magneto	C.B.	Magneto *	C.B. P.B.X.
Pyramid Cordless 4 * 6 and 10 line (including trunks) Corded Wall Pattern 20 and 30 line + trunks. Floor Pattern 100 line + trunks. Several 100 or 200 line 'A' (local) boards + one or more 'B' (trunk) positions.* (With and without subscribers or trunk multiple.)	Non multiple 200 line + 18 trunks (max.) Multiple exchange. Subscribers 'A' and sleeve control trunk positions catering for up to 2000 subscribers.	Obsolescent. Some still in service using Pyramid and Wall pattern boards. All new P.B.X's in Magneto areas are C.B. P.B.X's. * Indicates obsolescent types.	Cordless 1 + 3 * Cordless 2 + 4 Cordless 3 + 9 Indicator signalling 10 + 30 (max.) Indicator signalling 15 + 80 (max.) Lamp signalling 15 + 80 (max.) Note: 3 + 9 indicates 3 exchange lines + 9 extensions.

5. AUTOMATIC EXCHANGE PRINCIPLES.

5.1 The first automatic exchange installed in Australia was at Geelong, Victoria, in 1912, and the Department subsequently adopted the policy of making automatic the exchanges in capital cities and large country centres. In more recent years this policy has been extended to include small rural exchanges.

There are many different types of automatic systems in use in the world, but in Australia the step-by-step system is the one in common use. Its inventor was Strowger (U.S.A.) whose first patent is dated 10th March, 1891. Although many modifications and refinements have been introduced, the present system does not differ in principle from the original system.

The system is a decimal system with a 100 line exchange as the basic unit. Perhaps the easiest approach to this basic 100 line unit is via a 100 line manual switchboard. Fig. 65 shows the jack field of such a switchboard, together with No. 1 cord circuit whose position in the cord shelf is slightly to the left of the jack field.

Assume, now, that the operator answers a calling subscriber with the answering plug of No. 1 cord circuit, and that the subscriber requires subscriber Number 89. The operator plugs the calling plug of No. 1 cord circuit into jack 89 and rings. The movement of No. 1 calling plug from its position in the plug shelf to jack 89 is a diagonal movement, as shown in Fig. 65. This diagonal movement can be resolved into two movements -

A vertical movement, which selects the particular tens row of jacks required, and

A horizontal movement, which selects the unit required in that row.

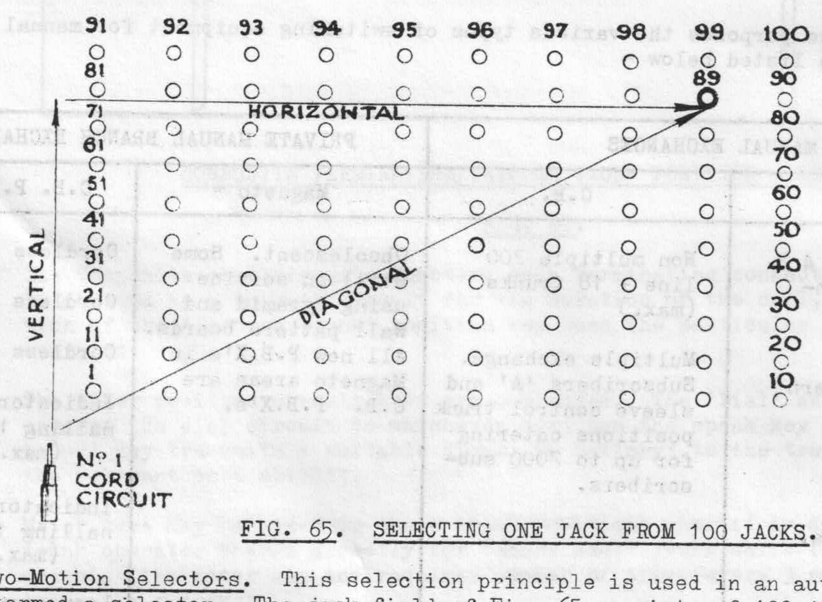
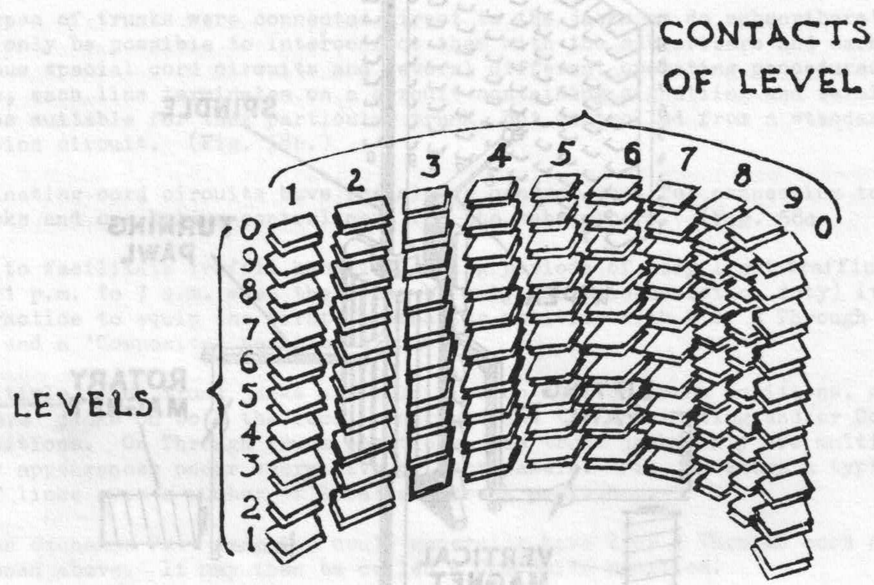


FIG. 65. SELECTING ONE JACK FROM 100 JACKS.

5.2 Two-Motion Selectors. This selection principle is used in an automatic mechanism termed a selector. The jack field of Fig. 65 consists of 100 jacks, each jack containing two springs to which the two sides of a subscriber's line are connected. These 100 jacks are arranged in 10 rows, each row containing 10 jacks. What could be regarded as the "Contact Field" of a 100 line selector is similarly arranged. The contact field is termed a contact "bank" and consists of 100 sets of contacts, each set containing two contacts to which the two sides of a subscriber's line are connected.

These 100 sets of contacts are arranged in 10 rows, each row containing 10 sets of contacts. This contact bank is arranged in the arc of a circle as shown in Fig. 66. This merely illustrates the principle of a selector contact bank, and excludes such features as insulation, the method of holding the bank together and so on. (Fig. 68 provides more information.)



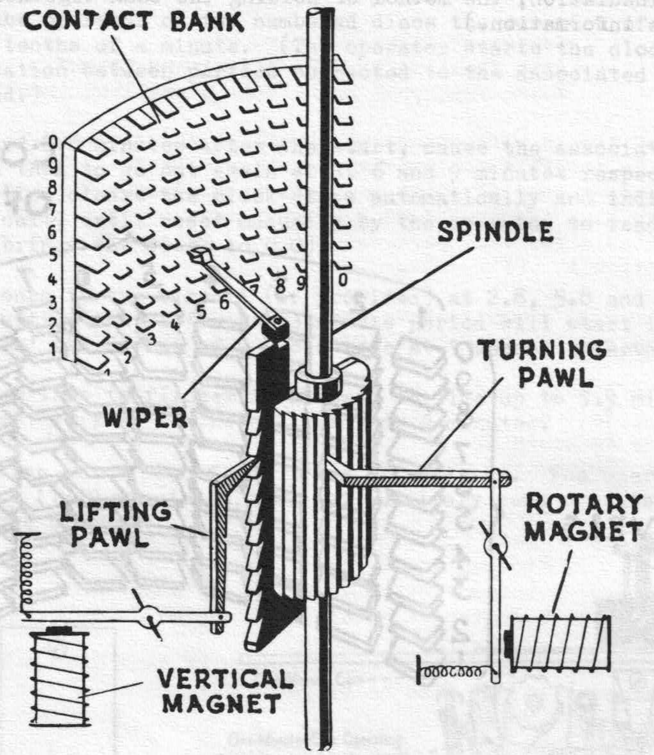
SELECTOR CONTACT BANK.

FIG. 66.

The equivalent of the calling plug in Fig. 65 is a pair of insulated contact brushes called wipers which are attached to a spindle, generally called a shaft. The normal position of these wipers is to the left and below the lowest row of contacts. This shaft is capable of a vertical and a rotary movement. The vertical movement carries the wipers up the side of the bank in just the same way as the vertical component of Fig. 65 carries the calling plug up the side of the jack field. The rotary movement carries the wipers over the sets of bank contacts in the row reached by the vertical movement in just the same way as the horizontal component of Fig. 65 carries the calling plug across the row of jacks reached by that vertical movement. The rows of contacts in the bank are termed "levels".

Since two distinct motions are necessary to select a particular bank contact the mechanism is known as a bimotional selector (sometimes a bimotional switch).

The shaft and wipers are moved vertically by the armature of an electromagnet called the vertical magnet. The armature of this vertical magnet is attracted when current flows through the winding of the magnet, and a pawl carried by the armature engages the underside of teeth attached to the spindle or shaft, as shown in Fig. 67. The design and adjustment of the mechanism is such that each attraction of the armature lifts the shaft and wipers a distance equal to that between two levels.

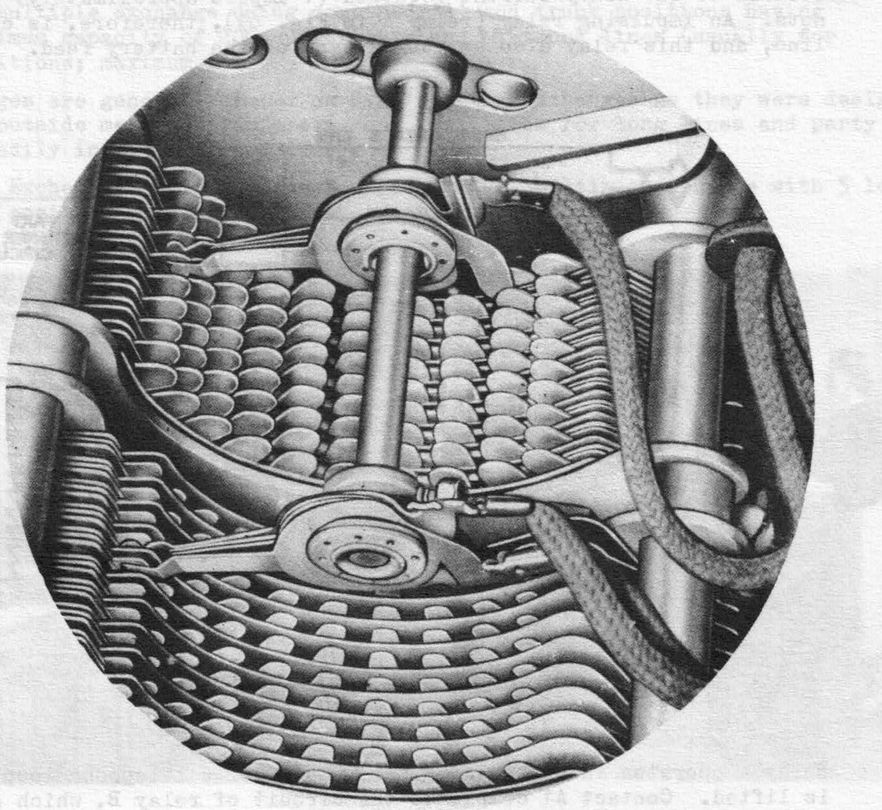


METHOD OF MOVING SHAFT AND WIPERS.

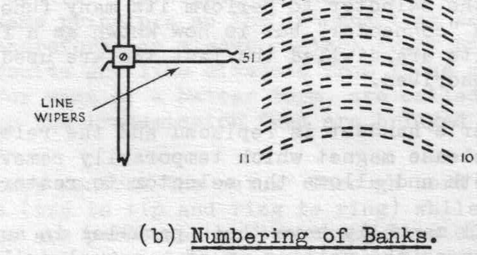
FIG. 67.

Thus, in order to raise the wipers to the third level, the circuit to the vertical magnet must be closed and opened three times. The first closure of the circuit attracts the armature, the pawl engages the underside of the appropriate vertical tooth and the shaft moves to lift the wipers from their normal position to a position opposite the first level. When the circuit to the vertical magnet is opened after this operation, the armature resumes its normal position under spring tension. On the circuit to the vertical magnet being closed again, the armature is attracted once more and the shaft is moved to lift the wipers from the first to the second level. Thus, the operation of selecting the particular level or row of bank contacts required depends on the circuit to the vertical magnet being closed and opened a number of times corresponding to the level required. (The wipers are normally attached to the bottom of the spindle or shaft and not as shown diagrammatically in Fig. 67.)

The operation of selecting the particular set of contacts in the level reached by the vertical movement is carried out by closing and opening the circuit to another magnet called the rotary magnet. Each operation of the rotary magnet attracts the armature of that magnet and causes a pawl carried by that armature to engage in one of a number of teeth cut around a hub of the shaft, as shown in Fig. 67. This action rotates the shaft and wipers, step by step, to the set of bank contacts corresponding with the number of times the circuit to the rotary magnet is closed.



(a) View of Bank and Wipers.



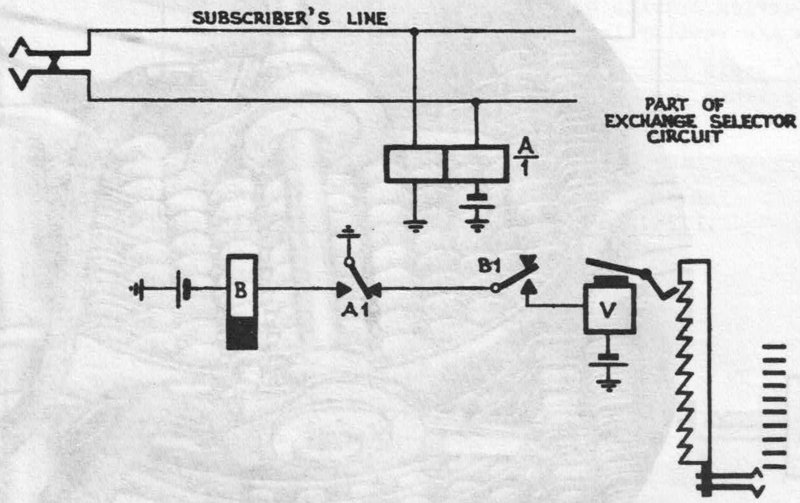
(b) Numbering of Banks.

FIG. 68. BANKS AND WIPERS.

5.3 Fig. 68 shows a typical contact bank and the method of numbering.

Note that there are two banks, the lower one being the line connections, requiring one hundred insulated pairs of contacts arranged in ten levels. The upper bank is similar in arrangement to the line bank, except that only single contacts are necessary. This contact, known as the private contact, is the equivalent of the sleeve wire in a multiple manual exchange, and is used for the engaged test, metering and other purposes.

5.4 Associated with the selector mechanism are several relays arranged so that the selector will perform its required functions. It is not practicable to operate the selector magnets in series with the subscriber's line circuit and dial contacts because of the heavy current required (1 ampere approximately) to operate the magnets. An impulsing relay (relay A in Fig. 69), therefore, is connected to the line, and this relay also serves as part of the battery feed.



VERTICAL STEPPING OF SELECTOR.

FIG. 69.

Relay A operates in series with the subscriber's telephone loop when the receiver is lifted. Contact A1 completes the circuit of relay B, which also operates. When the subscriber dials the first digit, a number of interruptions in the line current (pulses) corresponding to the digit dialled, are transmitted. Relay A responds to the pulses, but relay B, being slow to release, will hold during the periods when A1 is normal. With A1 normal and B1 operated, a circuit is completed for the vertical magnet, which will operate with each pulse and cause the selector shaft and wipers to be lifted a number of steps according to the digit dialled. The wipers will now be standing alongside the bank level containing the required number.

At the end of the first train of pulses, relay A remains operated and the release of a third relay, causes a change in the circuit. When the second digit is dialled the pulses from contact A1 are directed to the rotary magnet in a similar manner to that described above for vertical stepping. This positions the wipers on the particular rotary contact for that level corresponding to the second digit.

Connection between two subscribers may thus be established. Actually at least nine relays are necessary to enable the selector to perform its many functions. This type of switch was once called a "connector" but is now known as a final selector; since even when six or more digits are dialled the last two are used to position a selector in the manner just described.

At the end of the call the caller's handset is replaced and the release of the relays cause the operation of a release magnet which temporarily removes the latches from the vertical and rotary teeth and allows the selector to restore to normal.

5.5 The operations in switching a call manually have their parallel in automatic working. The following summary compares the setting up of a manual call with the equivalent steps to set up a call automatically.

C.B. MANUAL. Subscriber Removes Receiver.	AUTOMATIC. Subscriber Removes Receiver.
Lamp glows on answering position.	Automatic mechanism seized.
Operator inserts plug into answering jack.	Subscriber dials.
Operator ascertains the required number and tests in the multiple.	Automatic mechanism extends the caller to the bank contacts of the required number and tests.
If the called line is free, the operator inserts a calling plug into the jack and depresses the ringing key, thus sending a calling signal to the required number.	If the called line is free, the mechanism sets up conditions for calling the required number.
If the called number is already engaged, the operator informs the caller, either orally or by means of a signal, that the connection cannot be completed.	If the required number is "busy" the mechanism transmits a busy signal to the caller.
When the call matures, the operator meters it against the caller.	When the called party answers, the call is metered against the caller.
On completion of the call, supervisory signals are displayed to the operator, who takes down the connection.	On completion of the call, the mechanism is immediately released and becomes available for other calls.

During the progress of the call, and until the connection is released, both the calling and the called lines are made busy, thus guarding them from intrusion. In the manual case, the circuits affected are marked engaged, for as long as the connecting plugs remain in the respective jacks.

5.6 Supervising the Call. As indicated earlier, to enable the caller to know how a call is progressing, a system of tones is provided. The tones have different characteristics; the significance of the tones are known to the subscribers who are thus provided with a means of knowing whether the call is progressing satisfactorily or whether it should be abandoned. Certain tones have been set down as standard, but some of the older exchanges have tones which differ from these standards.

A more modern method of advising the calling subscriber of the progress of the call is by reproduction of a voice repeating such words as "Number engaged", "Dial now" or "Number unobtainable". So far, it has been used in Australia for trial purposes only.

The standard tones are as follows -

Dial Tone. This tone is transmitted to the caller when his line has been extended to a free mechanism - the tone indicates that the call may be commenced. The tone continues until the first digit in the called number is dialled by the caller. It is a continuous purring low note.

Ring Tone. This tone indicates to the caller that the call has proceeded satisfactorily and that ringing conditions have been set up, and may be represented by -

Burr--Burr-------Burr--Burr-------Burr--Burr. (Fairly High Pitched.)

Busy Tone. This tone indicates to the caller that the call is not progressing satisfactorily, due either to the called party being already engaged or to the connecting circuits involved in setting up the connection being engaged. The tone implies that the hold up is temporary and the call may be attempted later. It is a high pitched tone interrupted at regular intervals, thus -

Buzz-------Buzz-------Buzz-------Buzz-------Buzz.

Number Unobtainable Tone. This tone indicates to the caller that the call should be abandoned. The tone may be given when non-existent numbers are called or numbers which are disconnected. It is a high pitched tone similar to the busy tone, but interrupted only once every 3 to 5 seconds.

Standard Tones used in Automatic Systems.

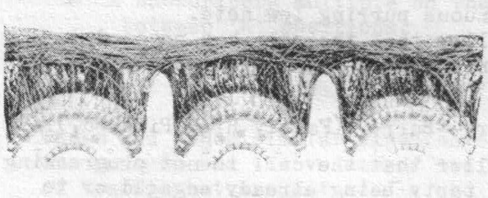
Name of Tone	Frequency, etc.	Note Given
Dial	33 cycles per second continuous	Low (purr)
Ring	400 cycles per second superimposed on the 16 c/s ringing current, interrupted as follows - 0.4 sec. (On) 0.2 sec. (Off) 0.4 sec. (On) 2.0 sec. (Off)	Medium pitch
Busy	400 cycles per second interrupted as follows - 0.75 sec. (On) 0.75 sec. (Off)	High pitch
Number Unobtainable (N.U.)	400 cycles per second interrupted ½ second in 3 (or 5) seconds.	High pitch

It will be clear that the characteristics of the tones must differ sufficiently to enable them to be readily distinguished. The tones in most exchanges are derived from interrupters associated with the exchange ringing machines.

Note. A pure tone of 33 cycles per second would be inaudible to many people and would not be transmitted by most trunk lines. Dial tone therefore while having this fundamental frequency is made so rich in harmonics that a very distinctive tone results, as most of the sound energy is actually of a much higher frequency.

5.7 Simple 100 Line System. A simple 100 line automatic exchange could consist of one final selector per line, that is, 100 final selectors. Each of the subscribers must be represented by contacts in the banks of every switch provided, and this is arranged by connecting similarly numbered contacts on all banks together by means of multiple wiring. (See Fig. 70.)

That is each of the 100 lines has 100 multiple appearances, one on the bank of each of the 100 selectors.



BANK MULTIPLE WIRING.

FIG. 70.

When a subscriber lifts the receiver to make a call, a final selector is taken into use, and by dialling two digits, the required connection is made. To prevent the final selector associated with the called line being seized, a pair of relays, designated L and K, are provided for each line. These function in a similar way to the line and cut-off relays of a subscriber's line circuit in a C.B. manual exchange, the operation of the K relay on an incoming call disconnecting the L relay and final selector and giving a clear line to the called subscriber.

Fig. 71 shows a trunking diagram of a call through such a 100 line exchange. Subscriber No. 21 is calling No. 30 and, on lifting the receiver, final selector No. 21 is seized. This is stepped up 3 levels by the first digit dialled and on to contacts 30 by the second digit and, providing subscriber 30 is disengaged, ringing current would be applied to the line. The operation of relay K disconnects final selector No. 30, preventing false operation.

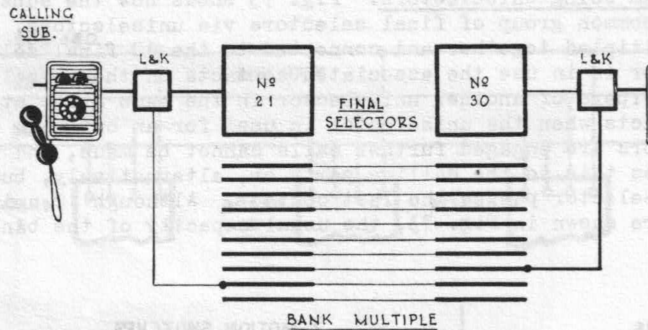


FIG. 71. SIMPLE 100 LINE EXCHANGE.

On outgoing calls from subscriber No. 30, the L relay would operate and final selector No. 30 would be used.

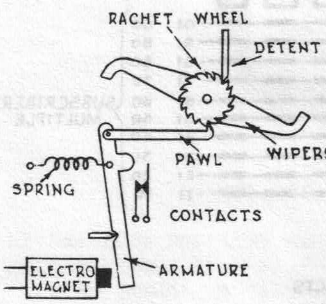
The 100 line exchange described would require 100 final selectors and banks. Each subscriber's line would have a final selector which would be used when that subscriber originated a call, but would not be required on calls from other telephones. If the 100 telephones were all in use, only 50 of the final selectors would be required. In fact, only a few subscribers are likely to be using the telephone at any one time, depending on their calling rate. Under average conditions, about 10 final selectors are required to handle the greatest number of simultaneous calls from 100 subscribers.

5.8 Uniselectors. As the two-motion selector is expensive it is economical to provide only sufficient to handle the normal traffic load and to give the 100 subscribers access to these as a common group. This is made possible by using a cheaper item of equipment, known as a uniselector, (one-motion selector) individual to each line.

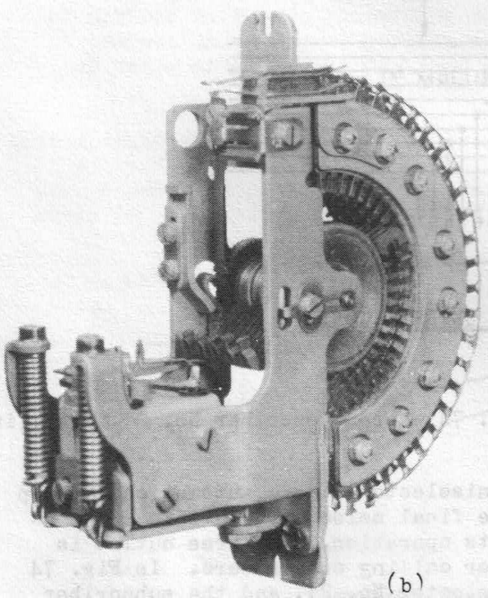
Rotary motion uniselectors are now generally used. In this type a ratchet mechanism is controlled by an electromagnet and armature which are operated and released in quick succession. The ratchet wheel is attached to a spindle to which the wipers are clamped, and these move in one plane only to engage the bank contacts arranged in an arc. The principle of operation of a common type of mechanism is in Fig. 72a.

When the magnet is energised the armature slides the pawl into the next ratchet wheel tooth. When current ceases in the magnet coil the armature restores to normal under the spring tension; the pawl draws the ratchet wheel forward one step which moves the wipers on to the next bank contact.

Fig. 72b shows a modern uniselector which uses this principle. Several other types are in use, one type having a small electric motor to advance the wipers.



(a) Principle.

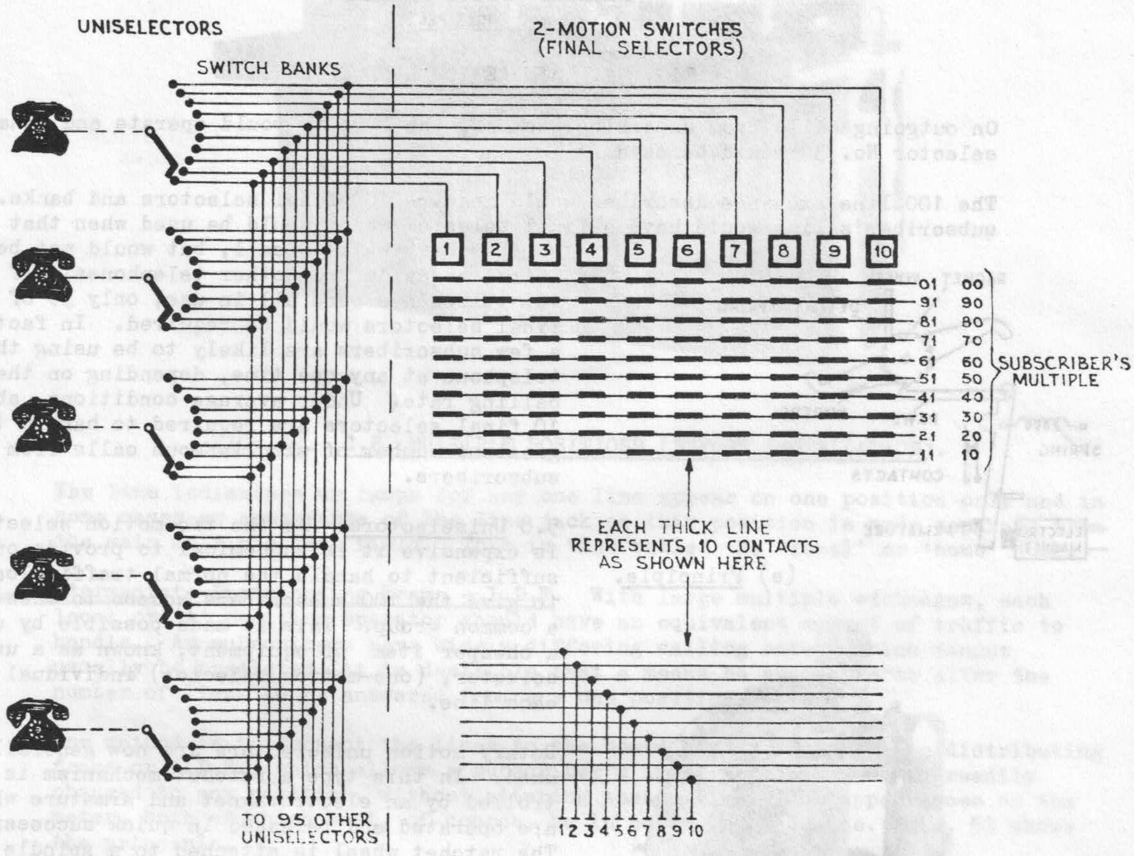


(b)

ROTARY UNISELECTOR.

FIG. 72.

5.9 100 Line System Using Uniselectors. Fig. 73 shows how the subscribers are connected to a common group of final selectors via uniselectors. The uniselector banks are multipled together and connected to the 10 final selectors. When a final selector is in use the associated contacts on the uniselector banks test busy, so that the wipers of another uniselector in the same group step over these particular contacts when the uniselector is used for an outgoing call. When the 10 final selectors are engaged further calls cannot be made, and the absence of dial tone indicates this to the calling party or, alternatively, busy tone is given when the uniselector passes the last contact. Although 10 uniselector bank contacts only are shown in Fig. 73, the usual capacity of the bank is 24 or 25 contacts.

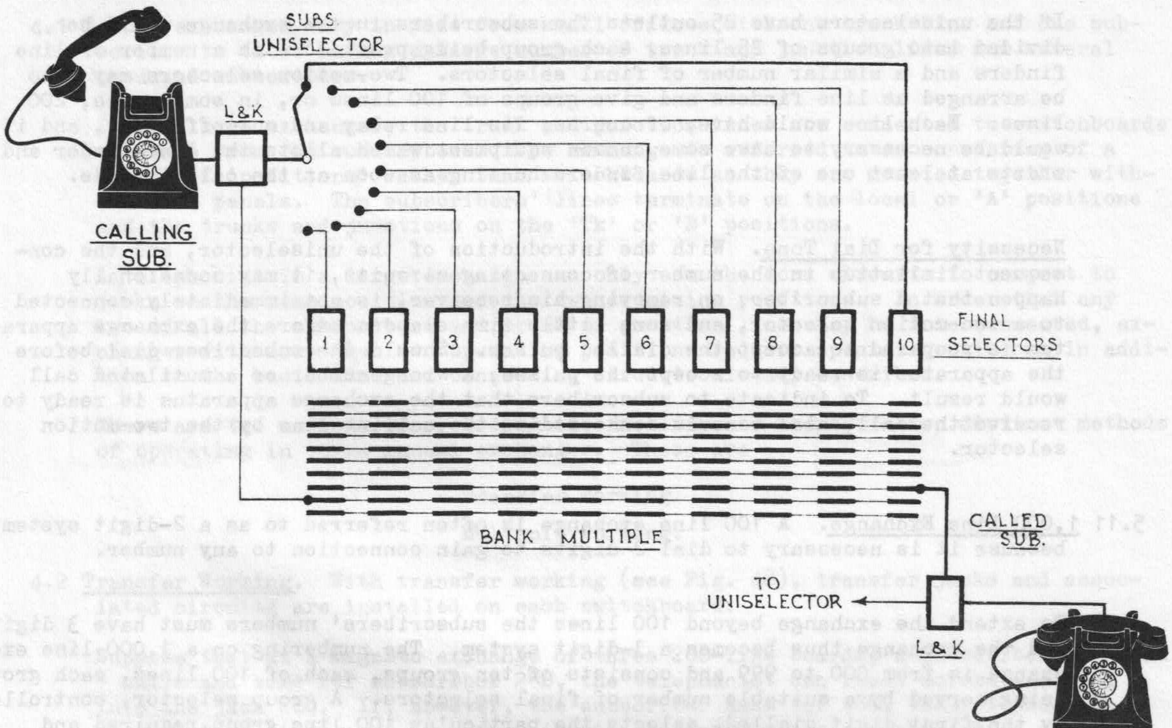


100 LINE EXCHANGE USING UNISELECTORS.

FIG. 73.

A simplified trunking diagram is shown in Fig. 74 where subscriber No. 21 is calling No. 30 as before.

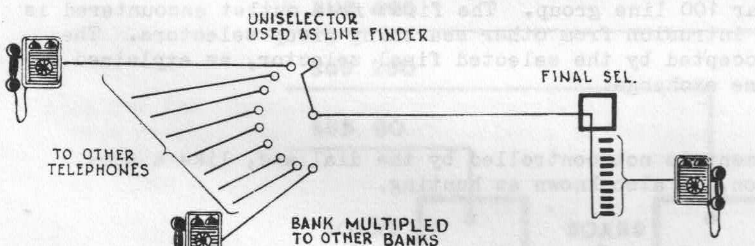
When the subscriber lifts the receiver, the uniselector wipers automatically step until they are standing on an outlet to a free final selector. This is known as a hunting action and requires no pulses for its operation. The free outlet is seized and guarded against intrusion from other calling subscribers. In Fig. 74 final selector No. 10 has been seized by uniselector No. 21, and the subscriber will proceed to dial the two digits 30. The call matures in the same way as described in paragraph 5.7.



100 LINE EXCHANGE USING UNISELECTORS.

FIG. 74.

5.10 Uniselectors as Line Finders. Providing a uniselector for each subscriber's line is not always the most economical arrangement. It is sometimes better to arrange the switching equipment as common to a group of subscribers rather than to make it individual to one line. Then it can be used by any one of a group, and, generally, it will be more economically used. In a small automatic exchange requiring only a few two-motion switches for the traffic, this will certainly be true. In these cases the uniselectors are coupled with a two-motion switch and the subscribers' lines are connected to the bank contacts of the uniselector as shown in Fig. 75.



PRINCIPLE OF LINE FINDER EXCHANGE.

FIG. 75.

There is no alteration in the mechanical operation of the uniselector with this arrangement. The removal of the receiver causes the wipers of an idle uniselector to hunt for the contacts of the calling party which, when found, are switched through to a two-motion switch. Thus, the uniselectors in use are similar to those in the switch per line scheme, but the number of uniselectors is much less than before. Uniselectors used in this manner are known as Line Finders.

If the uniselectors have 25 outlets the subscribers in the exchange would be divided into groups of 25 lines, each group being provided with a number of line finders and a similar number of final selectors. Two-motion selectors may also be arranged as line finders and give groups of 100 lines or, in some cases, 200 lines. Each line would have, of course, its line relay and cut-off relay, and it would be necessary to have some common equipment which allots the line finder and starts at least one of the line finders hunting as soon as the call is made.

Necessity for Dial Tone. With the introduction of the uniselector, and the consequent limitation in the number of connecting circuits, it may occasionally happen that a subscriber, on removing his receiver, is not immediately connected to a two-motion selector, and some little time elapses before the exchange apparatus is prepared to accept the dialled pulses. Should the subscriber dial before the apparatus is ready to accept the pulses, a wrong number or a mutilated call would result. To indicate to subscribers that the exchange apparatus is ready to receive the call, dial tone is connected to the calling line by the two-motion selector.

5.11 1,000 Line Exchange. A 100 line exchange is often referred to as a 2-digit system because it is necessary to dial 2 digits to gain connection to any number.

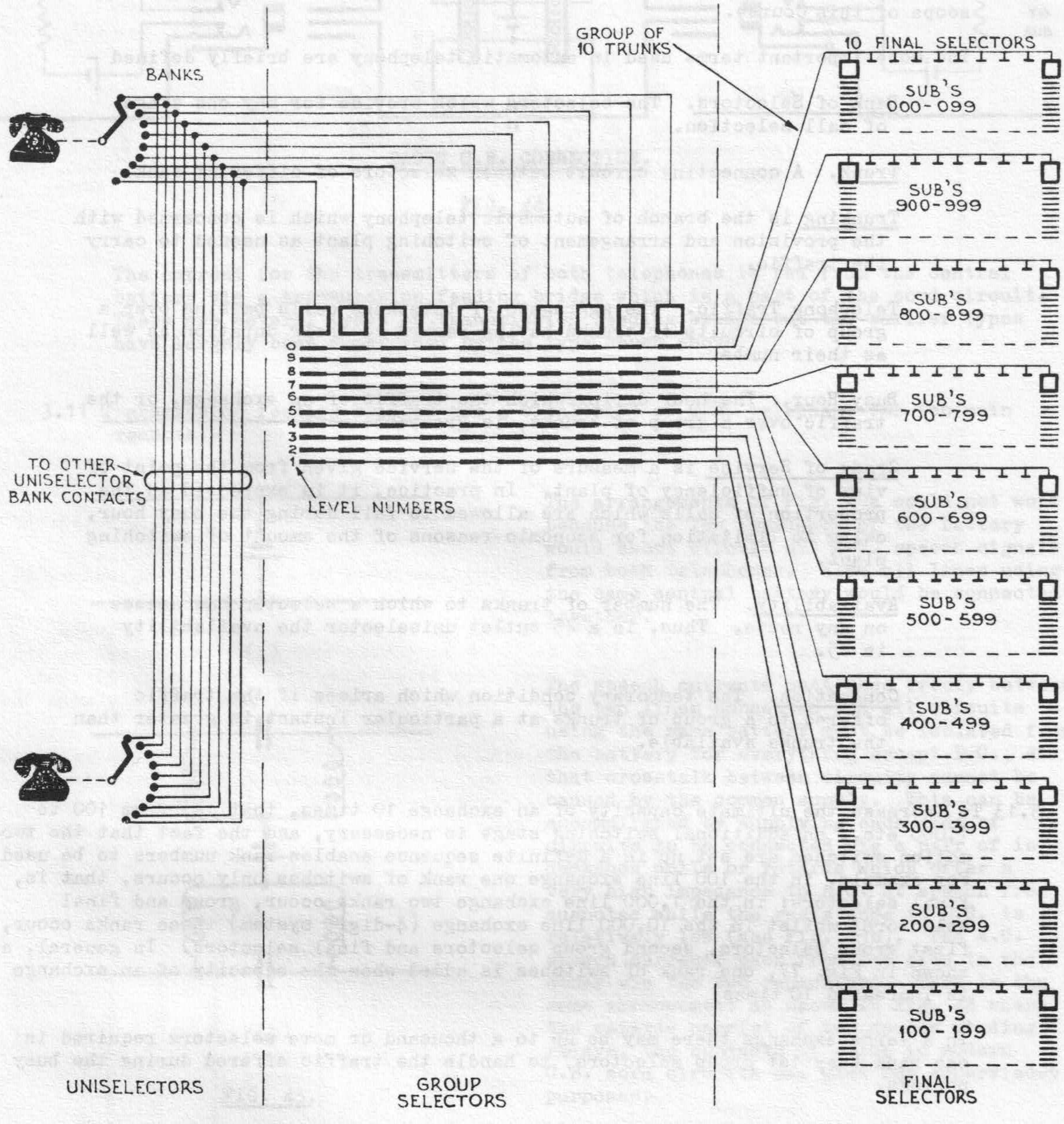
To extend the exchange beyond 100 lines the subscribers' numbers must have 3 digits, and the exchange thus becomes a 3-digit system. The numbering on a 1,000 line exchange is from 000 to 999 and consists of ten groups, each of 100 lines, each group being served by a suitable number of final selectors. A group selector, controlled by the first digit dialled, selects the particular 100 line group required and gives access to one of the final selectors serving that group.

The Group Selector is a two-motion selector having a mechanism which in all essentials is identical to the final selector. The vertical movement of this selector is controlled by the first train of impulses dialled but, unlike the final selector, the group selector is provided with an automatic rotary movement which comes into action immediately after the first digit has been dialled. The wipers are stepped over the contacts of the level reached, and these are wired to final selectors serving that particular 100 line group. The first free outlet encountered is seized and guarded against intrusion from other searching group selectors. The remaining two digits are accepted by the selected final selector, as explained in connection with the 100 line exchange.

This automatic rotary movement is not controlled by the dial and, like a subscribers' uniselector action, is also known as hunting.

Fig. 76 shows the trunking arrangements of a 1,000 line exchange. Assuming that 10 final selectors are sufficient to carry the average number of simultaneous calls incoming to each of the 100 line groups, then the banks of all the group selectors in the exchange will be multipled together.

5.12 It should be remembered that the large number of calls handled simultaneously by exchanges necessitates the use of a great many selectors and special methods of connecting between the outlets of one switching stage and the inlets of the next. It is not possible to represent this completely by diagrams, and Figs. 73 to 78 therefore can only illustrate the principle of selecting the required number, by what is actually a process of elimination - selecting one of 10 similar groups and one line of a hundred in that group.



PRINCIPLE OF 1,000 LINE EXCHANGE.

FIG. 76.

The automatic service in large cities is generally 5, 6, or 7 digit working, and provided by a network of separate exchanges rather than one large exchange.

This involves several stages of group selection, special facilities for junction working between exchanges and numerous other problems most of which are beyond the scope of this Course.

The more important terms used in automatic telephony are briefly defined -

Rank of Selectors. The selectors which provide for any one stage of call selection.

Trunk. A connecting circuit between selectors of different rank.

Trunking is the branch of automatic telephony which is concerned with the provision and arrangement of switching plant as needed to carry the traffic.

Telephone Traffic. The aggregate of telephone calls passing over a group of circuits or trunks having regard to their duration as well as their number.

Busy Hour. The hour during which the traffic of an exchange, or the traffic over a group of trunks, is greatest.

Grade of Service is a measure of the service given from the point of view of sufficiency of plant. In practice, it is expressed as the proportion of calls which are allowed to fail during the busy hour, owing to limitation for economic reasons of the amount of switching plant.

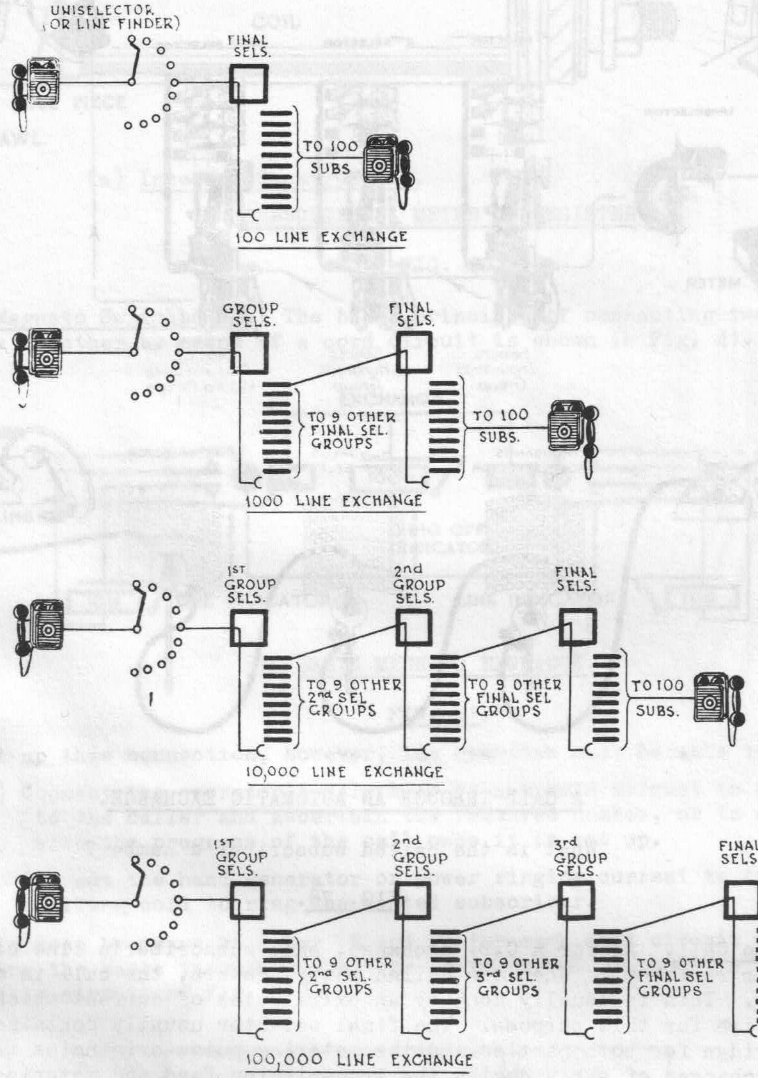
Availability. The number of trunks to which a selector has access on any route. Thus, in a 25 outlet uniselector the availability is 25.

Congestion. The temporary condition which arises if the traffic offered to a group of trunks at a particular instant is greater than the trunks available.

5.13 To increase the ultimate capacity of an exchange 10 times, that is, from 100 to 1,000 etc., an additional switching stage is necessary, and the fact that the two-motion switches are set up in a definite sequence enables rank numbers to be used. For example, in the 100 line exchange one rank of switches only occurs, that is, final selectors; in the 1,000 line exchange two ranks occur, group and final selectors; whilst in the 10,000 line exchange (4-digit system) three ranks occur, first group selectors, second group selectors and final selectors. In general, as shown in Fig. 77, one rank of switches is added when the capacity of an exchange is increased 10 times.

In a large exchange there may be up to a thousand or more selectors required in one rank (say 1st group selectors) to handle the traffic offered during the busy periods.

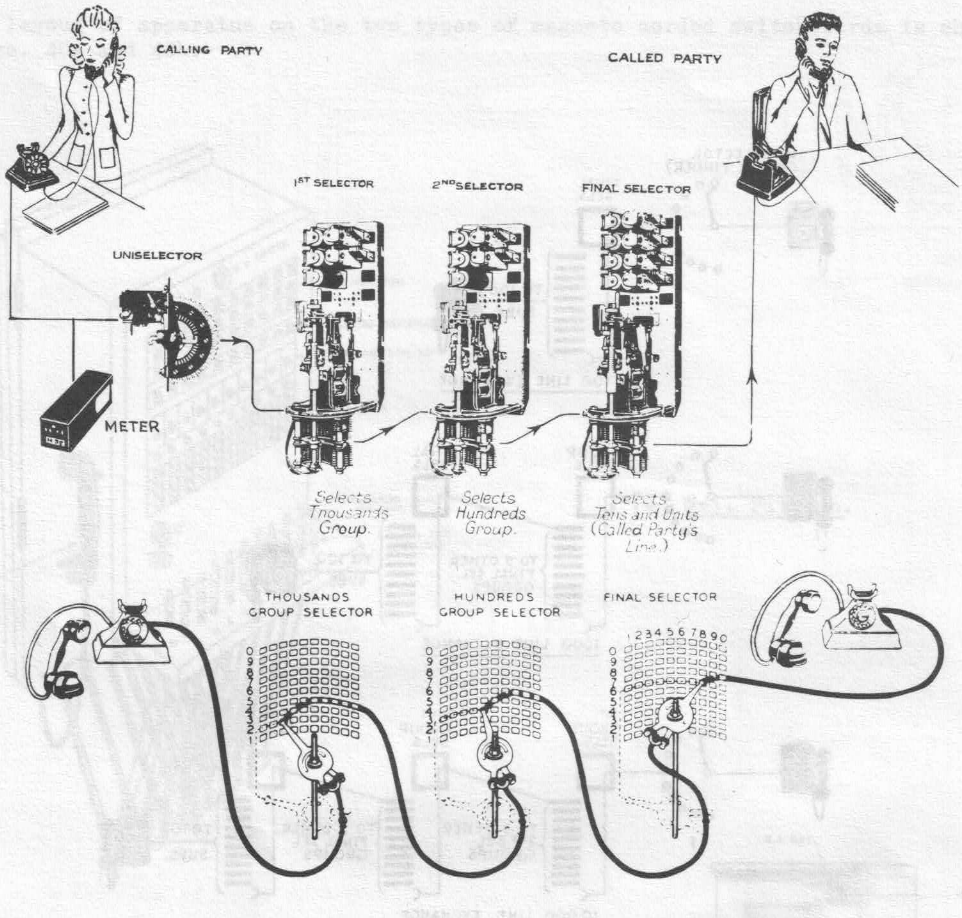
The number of contacts in a level was originally determined by the limits of the dial, which can give a maximum of 10 pulses for the final selector's last digit. As a similar bank is used for group selectors, the number of contacts searched was thus only 10, but there is no reason for limiting the contacts available, in fact, there are distinct advantages in most installations in increasing the number. Most group selectors now being used search two sets of bank contacts at a time, that is, there are 20 outlets on each of the 10 levels. Also most final selectors have access to two groups of subscribers' lines, a total of 200.



AUTOMATIC EXCHANGE TRUNKING DIAGRAMS.

FIG. 77.

Fig. 78 shows pictorially the switches used in an exchange with a capacity of 10,000 lines where 4-digits are dialled in selecting one subscriber from the 10,000. The lower sketch shows the actual position of the wipers at each switch on a call to a particular subscriber. The uniselector has been omitted, but the called subscriber's number may be ascertained from this sketch.

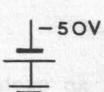


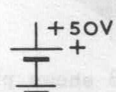
A CALL THROUGH AN AUTOMATIC EXCHANGE.

What is the called subscriber's number?

FIG. 78.

5.14 Metering the Call. As for a C.B. exchange, each subscriber's line circuit includes a meter (or register). When the called party answers, the call is metered against the caller. This is usually done by an extra pulse of current which is sent 'back' on the P wire for this purpose. The final selector usually contains a transmission feeding bridge for both parties and the metering pulse originates from this point. In some exchanges of early design the transmission feed and metering pulse may come from the first selector. In modern automatic (and C.B.) exchanges a small separate 'positive' battery is provided for metering in addition to the normal battery which is known as 'negative' battery. A negative battery has the negative pole at its full potential 'above' earth which means that the positive pole is earthed. A positive battery has the negative pole earthed as shown -





(a) Negative Battery. (b) Positive (metering) Battery.

5.15 Multi-Exchange Working. Metropolitan unit fee areas extend over hundreds of square miles and, if all subscribers were to be connected to a central exchange, many lines would be from 15 to 20 miles in length. To give the required standard of transmission performance, it would be necessary for line wires of much larger diameter than normal to be used on long lines.

By reducing the size of the exchange areas, the average length of subscribers' lines is correspondingly reduced and cable having lighter conductors may be used.

In Australia, the largest automatic exchanges are of 10,000 line ultimate capacity. This is decided from the average telephone density conditions and from the point of view of convenient size of buildings, and also the possibility of complete disruption of service in the case of fire or enemy attack is reduced.

Main Exchanges. If each exchange has a maximum of 10,000 lines, subscribers will dial five digits. The first digit serves to select the required exchange, the last four digits serving to select the required number from the 10,000.

The first level of the first selectors is not usually allotted since a false pulse may be transmitted if the switch hook is fumbled as the handset is lifted. Level 0 is sometimes allotted or reserved for the trunk exchange. Fig. 79a shows a multi-exchange area having eight exchanges.

As a subscriber in any of these exchange areas may desire to call a subscriber in any of the other exchange areas, it is necessary to provide junction circuits from each exchange to every other exchange. Under these conditions the exchanges are known as "main" exchanges.

Fig. 79b shows the junction routes necessary between the eight exchanges. Each connecting line represents a group of junctions in each direction, the number of junctions in each group depending on the traffic to be carried.

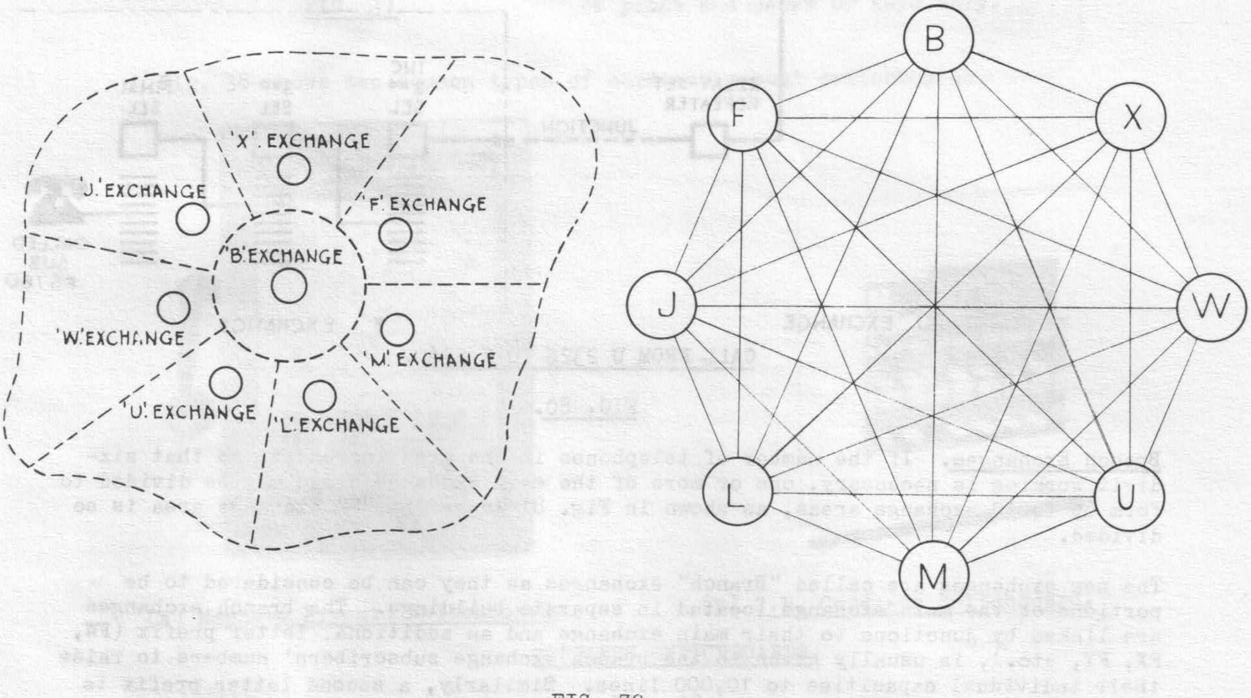


FIG. 79.

As a five-digit numbering scheme is used in the example quoted there will be 1st, 2nd and 3rd group selectors and final selectors in each exchange as shown in Fig. 80.

In each case the outgoing junctions are trunked from the 1st selector bank levels and terminate on incoming 2nd selectors at the distant exchange. The term "Incoming" selector is used to distinguish them from "Local" selectors, the latter being trunked from the local level of the 1st selectors.

Relay-Set Repeater. If the outgoing 1st selector levels were connected directly to the junction and thence to an incoming 2nd selector at the distant exchange, it would be necessary to provide three-wire junction circuits so that the holding and guarding functions of the private wire could be fulfilled. Also, for transmission purposes, it is necessary to provide a transmission bridge in the caller's exchange.

A relay-set repeater is connected between the 1st selector and the junction, and enables a two-wire junction to be used. It provides the transmission bridge, performs the necessary metering function and repeats dialled pulses over the junction to operate selectors in the distant exchange. Fig. 80 shows the route taken by a call from a subscriber on the "U" exchange to a subscriber on the "F" exchange.

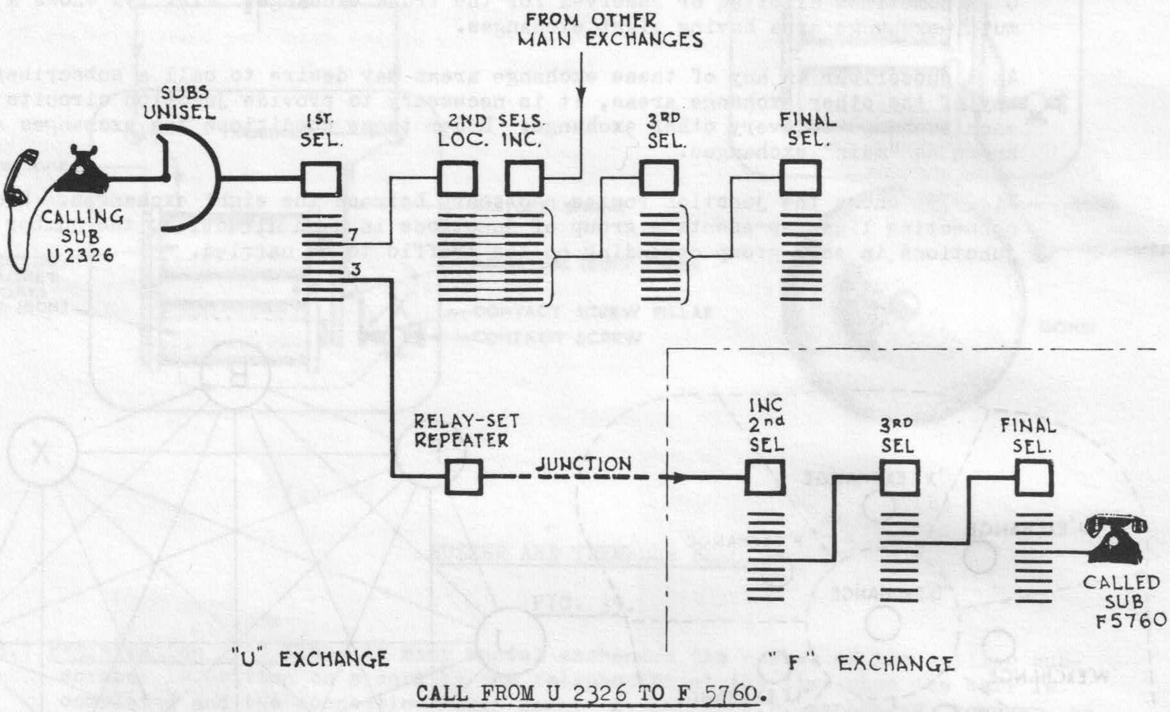
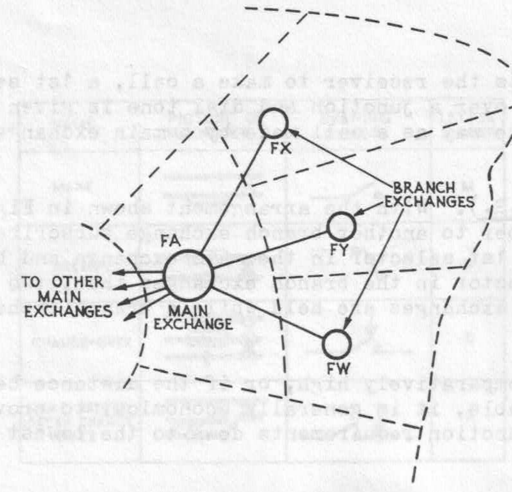


FIG. 80.

Branch Exchanges. If the number of telephones in the area increases, so that six-digit working is necessary, one or more of the main exchange areas may be divided to form up to 10 exchange areas, as shown in Fig. 81 where the "F" exchange area is so divided.

The new exchanges are called "Branch" exchanges as they can be considered to be portions of the main exchange located in separate buildings. The branch exchanges are linked by junctions to their main exchange and an additional letter prefix (FW, FX, FY, etc.), is usually given to the branch exchange subscribers' numbers to raise their individual capacities to 10,000 lines. Similarly, a second letter prefix is required to raise the main exchange capacity to 10,000 lines.



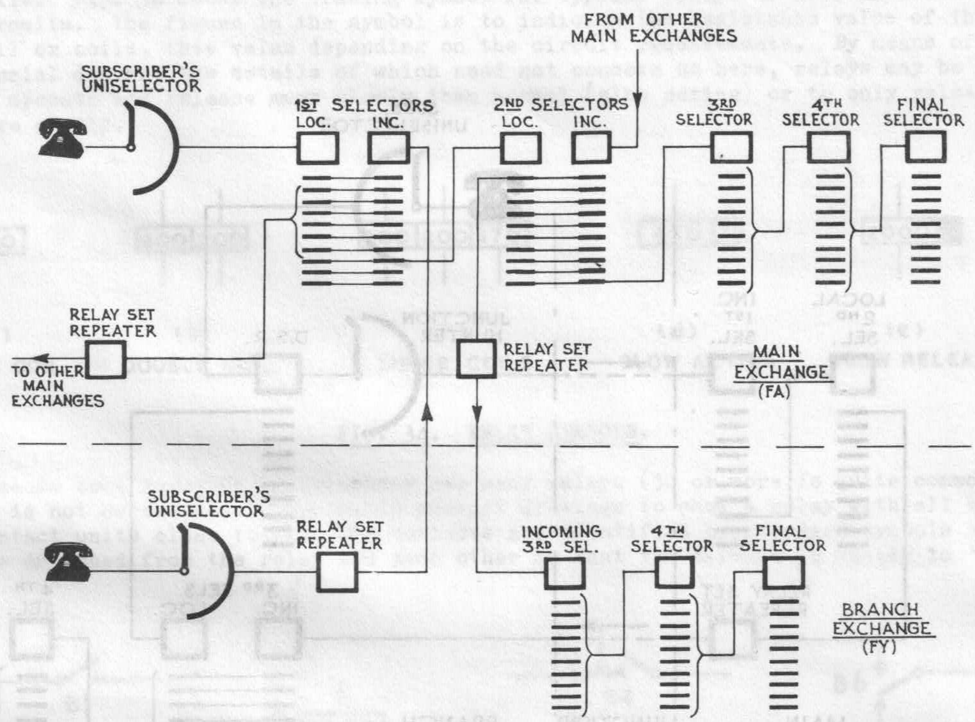
MAIN AND BRANCH EXCHANGES.

FIG. 81.

In deciding the numbering scheme for an automatic area, allowance has to be made for the number of lines that will ultimately exist in the area (that is, for 20 years ahead). It is, therefore, necessary to adopt a numbering scheme which can easily be expanded to meet the growing needs of the area.

After many years of rapid expansion the automatic networks of Sydney and Melbourne are reaching the stage where 7 figure working must be introduced. In the new scheme subscribers' numbers may be all figures instead of the familiar combination of letters and figures. Overseas experience indicates that this results in fewer wrongly dialled calls than when letter prefixes are used for 7 or more digits.

Fig. 82 shows the trunking arrangements for typical main and branch exchanges.



MAIN AND BRANCH EXCHANGE TRUNKING DIAGRAMS.

FIG. 82.

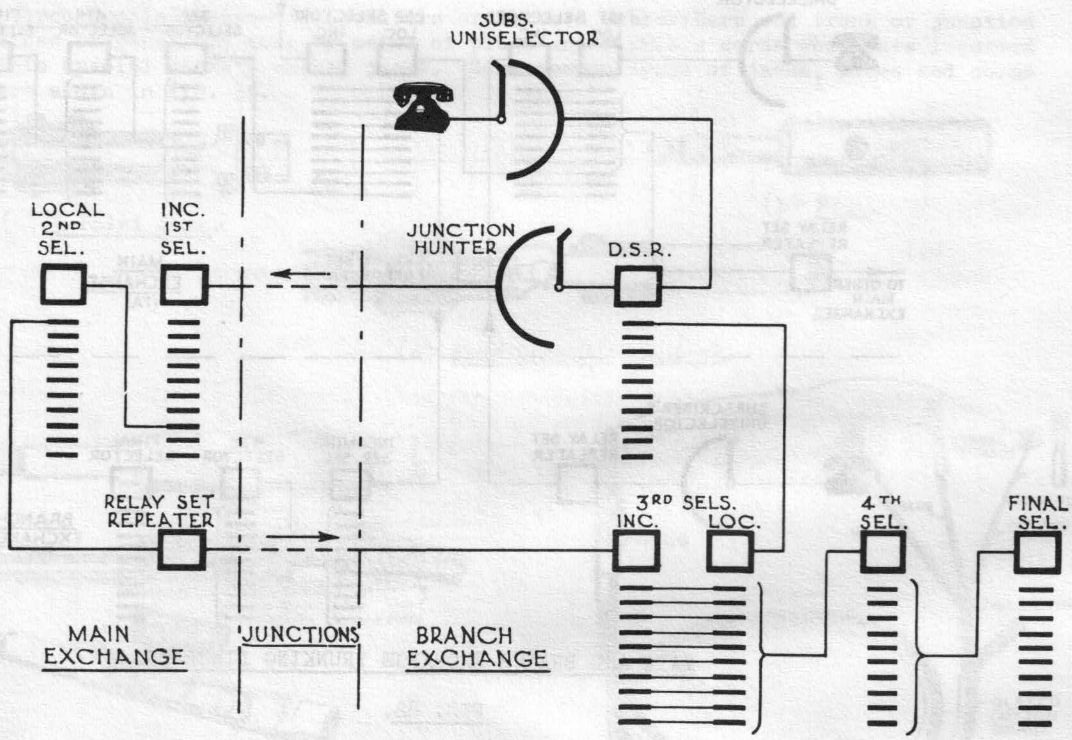
Calls to subscribers on the branch exchange have "F" as the first digit and are switched to 2nd selectors at the FA main exchange. Upon the second digit being dialled, (say it is Y) the call is extended over a junction to the FY branch exchange via a relay-set repeater. There an incoming 3rd selector is seized and accepts the third digit. The fourth digit operates a 4th selector and the final two digits serve to select the required number on a final selector.

When a branch exchange subscriber lifts the receiver to make a call, a 1st selector at the parent main exchange is seized over a junction and dial tone is given to the caller. The call is set up in the same way as a call made by a main exchange subscriber.

5.16 Discriminating Selector Repeaters (D.S.R.). With the arrangement shown in Fig. 82, a call from a branch exchange subscriber to another branch exchange subscriber passes over an outgoing junction to a 1st selector in the main exchange and back over a second junction to the 3rd selector in the branch exchange; thus, two junctions between the main and branch exchanges are held while a branch exchange local call is in progress.

If the proportion of local calls is comparatively high, or if the distance between main and branch exchanges is considerable, it is generally economical to provide special arrangements which keep the junction requirements down to the lowest possible figure.

A two-motion selector, known as a Discriminating Selector Repeater (D.S.R.) or Switching Selector Repeater (S.S.R.), was developed to meet this requirement. This switch combines the functions of both a selector and a repeater. It serves as a repeater on outgoing calls and as a selector on local calls. Fig. 83 shows a branch exchange trunking diagram with D.S.R's.



BRANCH EXCHANGE WITH D.S.R's.

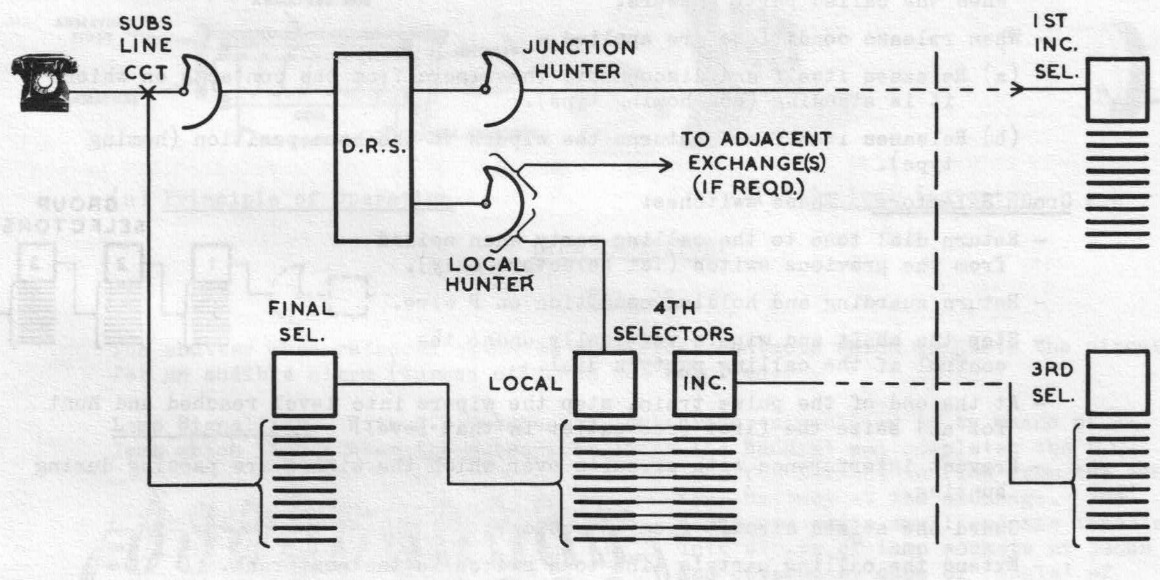
FIG. 83.

When a branch exchange subscriber lifts the receiver to originate a local call, a D.S.R. is seized. The associated junction hunter selects a junction to the main exchange, where a 1st selector is also seized. With the transmission of the first train of pulses both the selector and D.S.R. operate and the 1st selector hunts for a free 2nd selector. The D.S.R. shaft and wipers restore to normal after cutting-in on the dialled level, and the D.S.R. is said to have "absorbed" this digit. The second train of pulses operates the 2nd selector at the main exchange, and the D.S.R. at the branch exchange steps vertically, cuts in and seized a free local 3rd selector. The junction to the main exchange and the switches there are released.

If the call is not for the local exchange, the D.S.R. functions as a repeater, the wipers being disconnected.

Direct Switching Between Branch Exchanges. The direct distance between adjacent branch exchanges is often far less than the route via the main exchange, and, in many cases, it has been found economical to provide direct junctions. In such cases, the D.S.R. functions as a selector-repeater on calls between adjacent branch exchanges, and the junctions to the main exchange and the 1st and 2nd group selectors, are released to become available for other calls.

5.17 Discriminating Relay Sets (D.R.S.). In recent years a partial alternative to the discriminating selector repeater (D.S.R.) has been developed to perform the same functions without the use of a bimotional selector. Fig. 84 is the basic trunking diagram of the arrangement, the place of the D.S.R. being taken by a discriminating relay set (or discriminating repeater) and two uniselector hunters instead of one. The scheme is useful for small branch exchanges. The D.R.S. is capable of absorbing the first 3 digits if necessary, in which case the first rank of local switches are the fourth selectors.



TYPICAL BRANCH EXCHANGE TRUNKING USING D.R.S.

FIG. 84.

The D.R.S. has been developed into a very flexible (and space saving) item. Fig. 84 represents only one of the many possible trunking schemes. The digit counting circuits lend themselves to development using electronic equipment with further facilities resulting.

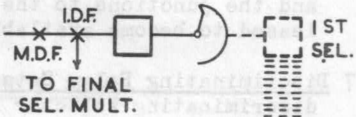
6. AUTOMATIC EXCHANGE SWITCHING FUNCTIONS.

6.1 In exchanges installed in Australia prior to 1938 most of the mechanisms were of Strowger design or similar. After that year most of the bimotional mechanisms were of a new British design known as the type 2000. The switching circuits were also redesigned to give 200 outlet group selectors (20 outlets per 10 step level) and 200 line final selectors. The basic principles were still Strowger; the earlier switching, however, became known as Pre-2000 type. In 1957, a new mechanism was introduced known as the SE.50 bimotional selector. For many circuits it is interchangeable with the 2000 type switch.

A few early exchanges use first group, final, and incoming selectors whose functions differ somewhat from those listed below - mainly in that the feeding bridge is in the first and incoming group selectors instead of in the final selector and junction repeater as is the practice in the other exchanges.

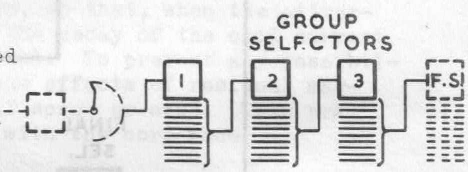
The following are the main functions of the various items of switching equipment in general use in Pre-2000 Strowger and 2000 type, step-by-step public exchanges.

6.2 Subscribers' Line Circuit. The functions are:



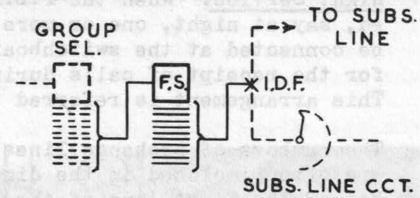
- Hunts for and seizes the first free outlet upon the lifting of the subscriber's receiver.
- Guards the selected outlet from intrusion.
- Guards the calling party's line from intrusion.
- Keeps the wipers disconnected during hunting, thus preventing interference with contacts over which they are passing.
- Extends the calling party's line to the switch ahead for the next stage of operation, and removes all bridges from the line wires.
- Prepares the circuit of the calling subscriber's meter for ultimate operation when the called party answers.
- When release conditions are applied -
  (a) Releases itself and disconnects the wipers from the contacts on which it is standing (non-homing type).
  (b) Releases itself and returns the wipers to the home position (homing type).

6.3 Group Selectors. These switches:



- Return dial tone to the calling party when seized from the previous switch (1st selectors only).
- Return guarding and holding condition on P wire.
- Step the shaft and wipers vertically under the control of the calling party's dial.
- At the end of the pulse train, step the wipers into level reached and hunt for and seize the first free outlet in that level.
- Prevent interference with circuits over which the wipers are passing during hunting.
- Guard the seized circuit from intrusion.
- Extend the calling party's line to a switch in the next rank.
- Should all outlets in the level be busy, connect busy tone to the caller, and operate an overflow meter.
- When release conditions are applied, release without interference to other circuits.
- Provide a supervisory alarm.
  (a) If seized and dialling does not take place (permanent loop conditions). Only provided on 1st and incoming selectors.
  (b) If the switch fails to release due to a mechanical fault when release conditions are applied.

6.4 The Final Selector. The functions are:



- When seized, returns guarding and holding condition on the P wire.
- Executes vertical and rotary movements under the control of the dial.
- Prevents interference with the lines passed over by the wipers during rotary motion.
- Tests the selected line, and prevents the calling line being extended to the called line while testing.
- If the called line is busy -
  (a) Guards against connection to the called line.
  (b) Transmits busy tone to the caller.
- If the called line is free -
  (a) Guards both lines from intrusion.
  (b) Allows the call to proceed.
- Cuts off the calling equipment of the called line.
- Sends out ringing current to the called line.
- Transmits ringing tone to the calling line to indicate that ringing conditions have been set up.
- When the called party answers -
  (a) Cuts off ringing current and ring tone.
  (b) Provides a transmission bridge to supply transmitter current to calling and called parties.
  (c) Operates the calling party's meter (if in the same exchange).
  and/or (d) Reverses the line current to the calling party for supervisory purposes.
- When the calling party clears, releases itself and restores connections to normal without interfering with other lines.
- Provides a supervisory alarm -
  (a) If the shaft fails to restore to normal when release conditions are applied. (Release alarm.)
  (b) If the called party's line is held by failure of the calling party to clear. (C.S.H. alarm.)

6.5 P.B.X. Final Selectors. A subscriber with more than one exchange line will naturally except that a call made to him will not receive the busy signal unless all his lines are in use.

In manual exchanges, this facility is obtained by grouping his lines together on the switchboard and by marking them in a distinctive manner (that is, by painting a white line immediately underneath the jacks), so that the telephonist will know that if the first line is busy she must test the other lines of the group in turn until a free line is found. The reply, "Number engaged", is not given unless all lines in the group are tested and found busy.

In automatic exchanges a similar arrangement is adopted, the lines being grouped together and marked, but in this case the marking is electrical instead of visual.

A subscriber having several exchange lines is usually provided with a switchboard. Although several lines may connect the switchboard with the exchange, only one number is included in the telephone directory, this being denoted by an asterisk. (Fig. 85.)

Gibbs A F L SpringvaleRdNunwdng WU 1729
Gibbs A J 36WilsonMBtn .... XB 4074
Gibbs A K 27HighfieldRdCant .. WF 3665
Gibbs A L CarlyleCrMontA ... WX 2598
Gibbs Angus 19MonaroRdKoo .. U 1653
GIBBS BRIGHT & Co 34Queen ★MB 2241
After 5 pm—
Genl Office MB 2243
Mrchndse MB 2249
Shippg MB 2244, MB 2245 or MB 2246
Timber Yard MB 2242
Lysaght Dept MB 2247
Timber&Plywood Dept MB 2248
Timber Yard BoundaryStSM .. MX 1784
Gibbs Bros (Agencies) Pty Ltd 317FlindersLa MU 3985
Gibbs Bros (Preston) Pty Ltd Produce Merchts 797HighPres JU 1159
GIBBS BROS & Sons Pty Ltd Textile Dyers ThompsonStAbfd JA 4445
GIBBS BURGE & Co Textile Dyers 9KentRich ★JA 5384
Gibbs C H 28YStAsh .... WM 2468

TELEPHONE DIRECTORY ENTRIES.

FIG. 85.

Night Service. When the P.B.X. switchboard is not staffed, say at night, one or more of the exchange lines may be connected at the switchboard to selected extensions for the receipt of calls during the unattended period. This arrangement is referred to as "Night Service".

The numbers of exchange lines selected for night service are often included in the directory, as well as the number of the first line of the P.B.X. group.

It is sometimes the practice to night switch the first exchange line to a continuously attended extension, such as the night watchman's. The object of this is to provide a service on the directory number in the event of a call from a subscriber who is unaware of the night service numbers.

The effect of night switching is to convert the P.B.X. group of exchange lines into a number of single direct exchange lines which terminate on the selected extensions. It is usually desired that, if the night service line is in use, another call made to it shall not be connected to any other free line in the group but shall receive busy tone.

The functions provided by the P.B.X. final selector in addition to those of the ordinary final selector are, therefore:

- Calls made to the first line of a P.B.X. group of lines are connected to the first free line in the group.
- Busy conditions are transmitted only when all lines in the group are busy.
- Calls made to lines other than the first line of a P.B.X. group are completed if the particular line is free, and receive busy tone if it is busy (night service facility).

This service can be given by special P.B.X. final selectors fairly readily when the number of subscribers incoming lines is not more than 10, that is the lines available from one level of the final selector.

For large group P.B.X. subscribers different arrangements are necessary. In one early system a more complex circuit and mechanism enables the final selector to hunt automatically over up to 10 levels in succession (100 lines). The modern method is to have finals that test only 10 lines each, but to spread the subscribers' incoming lines over several shelves of final selectors so that callers have access to 10 lines, but not all callers test the same ten lines; for example, 85 finals may have overall access to 30 lines on a particular level.

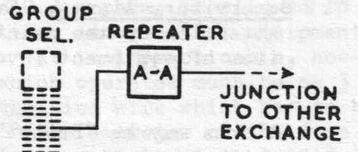
The three types of final selector are therefore known as Ordinary, 2-10 P.B.X., and Large group P.B.X. final selectors. (2-10 P.B.X. finals may be used for ordinary exclusive service subscribers as well as P.B.X. subscribers).

Final selectors of different systems vary in one other important respect. They are either calling party release or last party release.

Pre-2000 type exchanges have final selectors which are released as soon as the caller clears. In 2000 type and SE.50 exchanges the final selectors are held until both parties clear.

6.6 Relay-set Repeaters (Auto-Auto). The general functions of a relay-set repeater are:

- Connects a guarding and holding condition to the P wire to hold preceding switches and so allows the use of two-wire junction circuits.



- Provides a transmission bridge for the calling party.

- Repeats pulses from the caller over the junction to operate selectors at the distant exchange.

- When the called party answers, either -

  (a) Operates the calling party's meter (if in the same exchange).

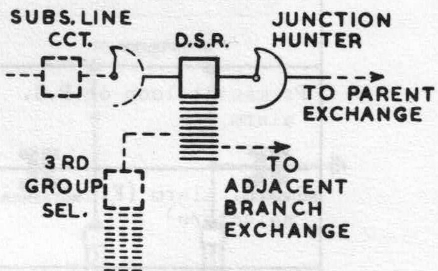
  and/or

  (b) Reverses the current flow to the calling line for supervisory purposes.

- When the calling party clears, releases preceding and succeeding switches, and guards the junction to cover the release of the incoming selector.

6.7 Discriminating Selector Repeaters. The pre-2000 type D.S.R. functions in a somewhat different way from the 2000 type D.S.R. but the following broad outline of functions applies to both.

- Connects a guarding and holding condition to the P wire to hold the subscriber's line circuit.



- Causes the junction hunter to search for a free junction to the main exchange.

- Repeats the pulses to the main exchange.

- The mechanism responds to the first one or two digits (or up to three for pre-2000 type) until sufficient digits have been dialled to discriminate (determine the route of the call).

- If the call is via the junction to the main exchange the D.S.R. no longer acts as a selector but as a repeater - performing all the functions listed above for the ordinary repeater (Paragraph 6.6).

- If the call is local, cuts in to the appropriate level (after vertical action under control of the dialled 2nd or 3rd digit) and hunts for a free switch in the next rank. The main exchange junction is released. The D.S.R. functions in this case as a group selector.

- If the call is for an adjacent branch exchange, cuts in to the appropriate level and hunts for a free junction to that exchange. The main exchange junction is released. The functions in this case are those of a group selector and a repeater (selector repeater).

7. MISCELLANEOUS FEATURES OF AUTOMATIC EXCHANGES.

7.1 Supervisory Alarms. Every automatic exchange has an alarm system to call the attention of the maintenance staff to any abnormal conditions and to indicate the item of equipment involved.

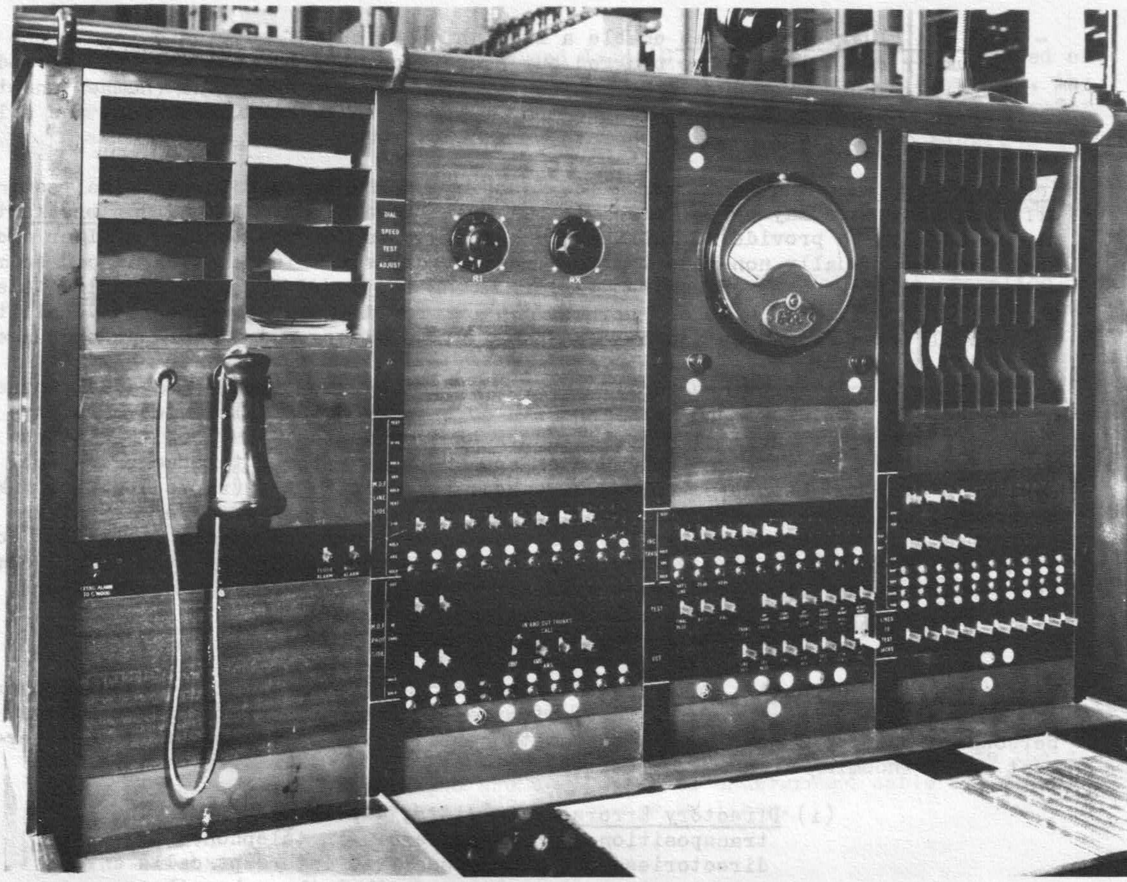
Alarms may be "Prompt" or "Deferred", the former requiring immediate attention, while the latter may be temporarily deferred without affecting the service of a group of subscribers.

Some normal conditions constitute a fault if they persist for longer than a certain time. For example, the release magnet is energised during the release of a selector, but, if it were to remain energised for long periods, it would overheat and possibly cause a fire. A delayed alarm circuit gives an alarm only if the condition is maintained for a certain minimum time.

The following table gives the principle alarms of a 2000 type exchange, and is fairly typical of the earlier types, although several variations exist, particularly in the periods of delay.

Alarm.	Delay Period.	Prompt or Deferred.	Cause of Alarm.
Fuse alarm	Nil	Prompt	Operation of a fuse.
Release alarm	9 seconds	Prompt	Failure of selector to restore to normal when its release circuit is energised.
Permanent loop or P.G. alarm	6 minutes	Deferred	First selector, incoming selector, or D.S.R. held without receiving pulses.
C.S.H. alarm (Final selectors)	3 minutes	Deferred	Calling or called subscriber holding after the other party has cleared.
Ring fail alarm	Nil	Prompt	Failure of ringing current
Charge fail alarm	Nil	Prompt	Operation of circuit breaker during battery charging.
Voltage alarm	Nil	Prompt	Voltage at busbars outside prescribed limits.
Meter battery fail alarm	Nil	Prompt	Failure of meter battery voltage.
Line finder alarm (Line finder exchanges only)	6 seconds	Prompt	Line finder fails to find the calling line.
Condenser alarm	Nil	Prompt	Breakdown of uniselector spark quench capacitor.

7.2 The Test Desk. Foremost amongst the testing equipment provided at automatic exchanges is the Test Desk, for there all subscribers' complaint reports are received and their probable causes diagnosed from the results of tests performed on the circuit. The test desk generally consists of a cordless floor pattern switchboard, and as shown in Fig. 86, is provided with a voltmeter and keys for testing and connecting purposes. Pigeon-holes are provided for fault dockets and subscribers' master cards. A number of positions may be installed, according to the testing requirements. In smaller exchanges the testing apparatus may be rack-mounted, in which case it is known as a Test Rack.



TEST DESK KEYBOARD.

FIG. 86.

The test desk or rack provides circuits enabling the testing officer to test or speak to any subscriber, junction or other line connected to the exchange. These circuits are:

- Test Selector Trunks by means of which the 'testing' officer, dials into a special test final selector to test a subscriber's line via the normal final selector multiple, I.D.F , and line circuit, for that line. He may either test out to the telephone or in to the line circuit, and make a test call via the subscriber's line, circuit. He may also 'guide' a subscriber who is having difficulty by listening across the circuit as the subscriber is dialling.

- Trunks to the M.D.F. - Exchange (arrester) side may be used for testing either in or out on any line which connects to the exchange equipment via an arrester. A special test 'shoe' is inserted in the arrester strip and a cord connects to a jack strip above the M.D.F. which is cabled back to the test desk.

- Trunks to the M.D.F. - Line (fuse) side are used mainly for testing out on new lines not yet jumpered to arresters, or junctions and miscellaneous lines which are not always provided with arresters. Either a special 'shoe' is used which fits in place of the two line fuses, or small clips which may be attached to any terminals.

- Test and Plugging up Lines enable a line which is out of service owing to one of a number of faults, to be plugged out of service, but be available for periodic testing. Subscribers calling the faulty line receive N.U. tone (number unobtainable). When the fault is cleared the line reverts to normal working, and a lamp lights on the test desk to show this has occurred.

Incoming trunks to the test desk allow Technicians and Linemen to call the testing officer, and tests may be performed 'back' over these lines. In and Out trunks terminate on keys to provide normal telephone facilities for the testing officer except that they are usually non-metering for incoming calls. This means calls can be made without operating a subscriber's meter or having to insert coins in a public telephone. Order-wire circuits or 'bothway' lines provide intercommunication facilities between all main exchanges and between each main exchange and its branch exchanges.

The Testing Circuit provides facilities for detecting the presence of a telephone on a line, or faults such as foreign earth or battery potentials, open-circuits, short-circuits, low insulation resistance. Line conductor and 'loop' resistance may be measured; a transmission test made on speech to and from a telephone. A subscriber's dial may be tested for pulse speed, pulse 'weight', (ratio of pulse make to break), and pulse count. A subscriber may be rung before or after a test is performed and if the subscriber has left the handset off the cradle (permanent loop) a 'howler' may be connected to the line to attract the subscriber (the 'howl' comes from the receiver; ringing current will not usually ring the bell loudly enough, if at all, when a line is in a P.L. condition).

7.3 The Interception Circuit. Under certain conditions, calls normally completed over the automatic equipment require to be diverted to a manual position to be given personal attention. Some of the circumstances in which it is necessary to intercept calls incoming to a subscriber's line are -

(i) Directory Errors. Misprints, duplicate entries, transposition of numbers, etc., in telephone directories make it necessary to intercept calls incoming to certain lines so that the subscribers affected are saved the trouble of answering calls intended for other subscribers, and enabling the callers to be advised of the correct number for future use.

(ii) Service Complaints by Subscribers. In the case of a subscriber complaining of the receipt of calls for another number, the interception equipment provides the means of investigating the subscriber's complaint, incoming calls to the subscriber being checked by the operator before being put through.

Special equipment is installed in automatic exchanges to provide this facility. The intercepted calls are generally diverted to a centralised position via a junction circuit. Interception relay-sets are wired to multipled jacks on the M.D.F. and, by means of a cord and test plugs, any subscriber's line can be associated with the interception equipment. Fig. 87 shows how the line to be intercepted is diverted from the exchange side of the M.D.F. to the interception equipment.

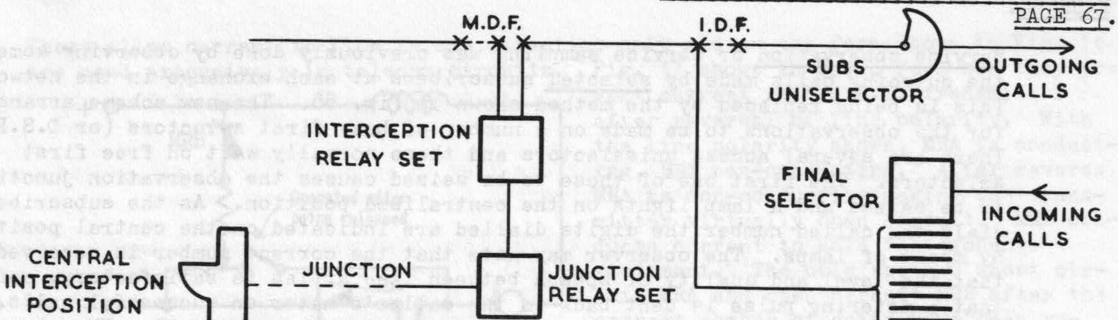


FIG. 87. INTERCEPTED LINE.

The main facilities provided by the interception circuit are:

- An incoming call for the intercepted line is diverted to a manual position where the call is indicated by the operation of a signal lamp.
- The operator answers the incoming call and, if necessary, switches it through to the intercepted line. A lamp signal is given until the called subscriber answers. The interception junction is then cleared in readiness for another call.
- If the call is not to be switched through to the intercepted subscriber, the operator advises the caller of the correct number. The junction may be cleared by operation of a key.
- Calls outgoing from the intercepted line are not affected, pulses being repeated in the same way as in an auto-auto repeater. The subscriber need not be aware that the line is intercepted.

7.4 The Changed Number Circuit. When a subscriber's number is altered due to a change of address, etc., it is necessary to intercept all calls to the old number and advise callers of the change in the telephone number. The arrangement is similar to the interception circuit except that there is no need to cater for outgoing calls.

The line is connected at the I.D.F. by means of jumpers to the changed number circuits. The changed number circuits may share the same junction to the central position as a number of interception circuits.

7.5 The Centralised Observation Circuit. The object of undertaking service observations is to obtain data regarding the quality of service given to subscribers. It is not practicable to provide separate observation equipment in each exchange and, in practice, a centralised observation centre provides the facilities for a number of exchanges in the district. From this centre, routine observations are carried out on the service obtained by subscribers in each exchange.

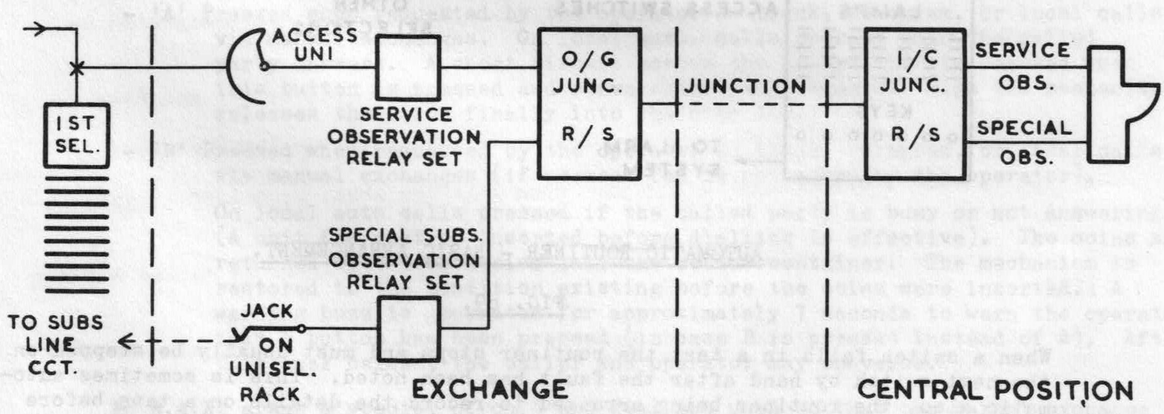


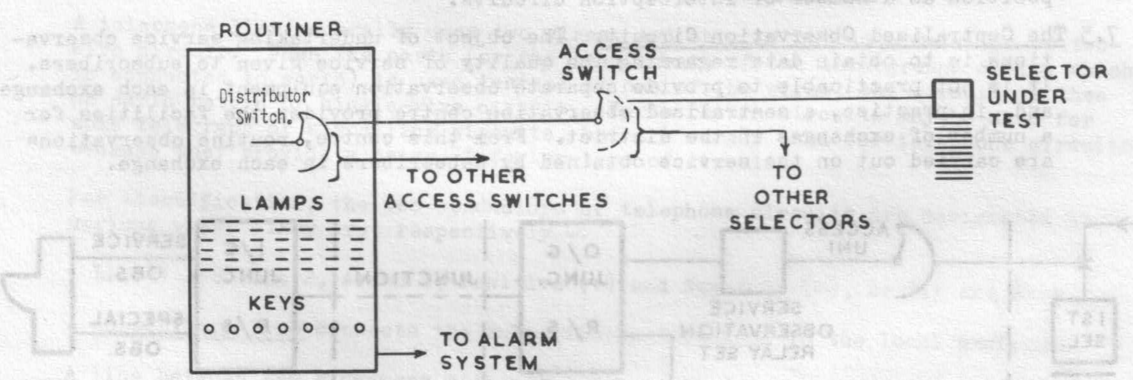
FIG. BASIC ARRANGEMENT. SERVICE SAMPLING AND SPECIAL (SUBSCRIBERS) OBSERVATION.

Service observation or service sampling was previously done by observing some of the outgoing calls made by selected subscribers at each exchange in the network. This is being replaced by the method shown in Fig. 88. The new scheme arranges for the observations to be made on a number of busy first selectors (or D.S.Rs.). There are several access uniselectors and these normally wait on free first selectors. The first one of these to be seized causes the observation junction to be seized and a lamp lights on the centralised position. As the subscriber dials the called number the digits dialled are indicated on the central position by means of lamps. The observer may note that the correct number is received, that the level and quality of speech between the parties is satisfactory, and that a metering pulse is sent back to the caller's meter on successful calls. The observer may then clear the junction to observe the next call. The observer may isolate any particular junction and exchange equipment when no more observations are required for a time.

The Special (Subscriber's) Observation circuit is used when it is desired to observe all the in and out calls of a particular subscriber. A special junction is necessary for each special observation circuit but one circuit may share the junction with the service sampling equipment as shown in Fig. 88. In this case the special observation circuit takes priority and if the subscriber on special observation makes or receives a call, any service observation in progress is immediately disconnected.

7.6 Routine Testing. Equipment is provided in automatic exchanges to enable all the functions of every item of switching equipment (selectors, repeaters, etc.) to be tested for correct operation. Portable test sets with key control are used in many exchanges, but in the larger 2000 type exchanges automatic routine testers (or routiners) are installed for each type of circuit to be tested. A typical exchange would have one or more group selector routiner, one final selector routiner, and one or more relay set repeater (R.S.R.) routiner.

The automatic routiner equipment is rack mounted and controlled by keys, the various tests applied being indicated by lamps. The routiner may be arranged to carry out a general routine, or a continuous routine of one switch. In a general routine the routiner tests in sequence all the items of equipment to which it has access. A basic block diagram of a typical routiner is in Fig. 89.



AUTOMATIC ROUTINER - BASIC ARRANGEMENT.

FIG. 89.

When a switch fails in a test the routiner stops and must usually be stepped on to the next switch by hand after the fault has been noted. This is sometimes automatic also, the routiner being arranged to record the details on a tape before stepping on. The routiner may be connected by a key to the main alarm to call the attention of the maintenance staff when a fault is encountered.

Routine testers are supplemented by artificial traffic equipment which continuously sets up a large variety of normal calls within a network, and like the routiner stops and brings up an alarm if any service irregularity occurs, for example, wrong number, no progress, faulty metering, etc.

7.7 Traffic Recording. In order to determine accurately the switch quantities required at each switching stage in a network, it is necessary to make periodic measurements of the traffic being carried by the various racks of equipment. This can be done by visual counting of the busy switches at frequent intervals by a team of observers. This is slow and liable to human errors. Automatic traffic recorders are installed as a part of most large exchanges and these provide a quick and more accurate check. The tests cover the busy hours and the aggregate of busy circuits is recorded either on meters like the subscriber's meter or on a specially calibrated voltmeter.

7.8 Tracing of calls in automatic exchanges requires a thorough knowledge of the functions of the various ranks of switches and the various methods of interconnecting them, plus the ability to interpret from 'trunking cards' the actual terminating point on the next rank of any one of the outlets from each of hundreds or thousands of selectors in the exchange. Practice is also necessary in rapid tracing of calls and local knowledge is a great asset as exchanges vary greatly in their layout, trunking, and methods of designating the racks and charts. When a call passes through several exchanges the call has to be traced through each in turn.

A call may be traced forward from the calling line toward the called number. This is done to find the cause or possible cause of a wrong number or no progress (no signal after all the digits have been dialled).

Tracing a call forward is a fairly straightforward process if the calling line can be held. No call can be traced if the caller hangs up before a Technician has had time to hold the connection independently of the caller. The best way to solve persistent calling troubles is for the caller to hold the unsuccessful call and advise the exchange on another line of all the details - calling party's number, number dialled, and result. Once the Technician has traced the call to the first selector or D.S.R., it is possible to clear the caller's line if he does not desire to wait while the call is traced.

A call may be traced backward from the called line to the caller. In this case, the tracing starts from the final selector. This is a much more difficult process and takes more time in most cases, as a great deal more searching may be necessary. As the calling number is not known (as in the case of 'nuisance' calls) it is necessary in most cases for the called party to keep the caller in conversation while the exchange is notified and the call traced.

There is an exception to this however. If the calling and called party are connected to the same 2000 type or Strowger exchange (and the more modern types) the complete connection may be held from the final selector if the Technician has time to locate the final selector and busy it by manually connecting the guarding and holding condition to the P wire. The call can then be traced back to the calling line even if the caller hangs up.

If the call is from another exchange busying the final selector will only hold the call back to the incoming selector. This will be some help in deciding from which exchange area the call may have come, but if the caller clears before the outgoing repeater in that exchange can be busied also, the connection drops out in that exchange.

7.9 Service faults in automatic exchanges occur mostly as a result of either electrical faults or mechanical faults. (This is apart from faulty operation of the telephone or switchboard which accounts for a large number of errors.)

After hundreds of thousands or millions of operations, relays, contacts, and switch vertical and rotary mechanisms wear to an extent where re-adjustment or replacement of parts is necessary. The need for this is detected in most cases by routine examinations, tests, etc., before the circuit fails in service. A switch can fail in service because of an intermittent fault which does not show up on test, or because a speck of dust temporarily insulates a relay or wiper contact which is worn. A dry joint may develop in the wiring and become open circuit between tests.

A complete failure will result in a no progress call. A partial failure can result in a switch having faulty response to pulses thus causing a wrong number. A selector may test into a circuit which is already busy causing crossed lines. Metering faults can occur if the meter does not respond to the metering pulse or if the pulse is too short or too weak. Normally, the meter operates only once per call and great care is taken by the designers to ensure that multiple metering cannot occur on unit fee calls. The stopping on busy fault referred to above may sometimes cause an unsuccessful call to be metered. A subscriber may claim a rebate for wrong numbers by immediately ringing complaints.

All the probable and possible causes of faults can never be listed. One type of fault may usually have a fairly common cause but sometimes unusual faults occur or common faults have unusual causes that may be met only once in a lifetime. The locating of such faults requires skill, patience and imagination.

7.10 Other types of Automatic Switching are in general use overseas and do not use the step-by-step method of selection. They are worth mentioning here because there are now examples of some of these systems operating in Australia and more may be introduced.

The Marker Control Uniselector System of Messrs. Siemens Brothers (Gt. Britain) is now in use for automatic switching of trunk calls in an Australia-wide network, and also at a suburban exchange in Victoria. The switching is performed by a high speed motor-driven uniselector having 104 contacts. A simple (ratchet) uniselector is stepped under the control of the incoming impulses and then marks the required group on the banks of the motor uniselector. The motor uniselector then drives to select the first free outlet in the marked group. Fig. 90 shows the basic principle of group selection. The same switches are used as line finders and final selectors so an exchange of this type has no bimotional selectors.

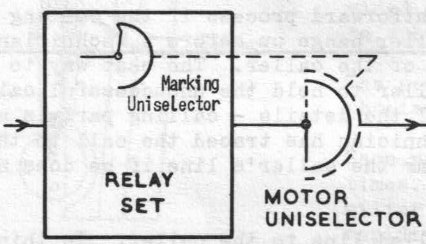


FIG. 90.

Crossbar Systems use a special mechanism which may be briefly (and roughly) described as two rows of special relays at right angles to each other, each row having crossing bars of contacts which are partly interdependent. Fig. 91 shows one type of crossbar switch. A form of marker control is commonly used to operate these switches. The dialled pulses are stored in a register which then sends the necessary information to the marker circuits which cause the operation of the crossbar magnets to establish the speaking path. Examples of this system are in use in Victoria as R.A.Xs. and a suburban branch exchange.

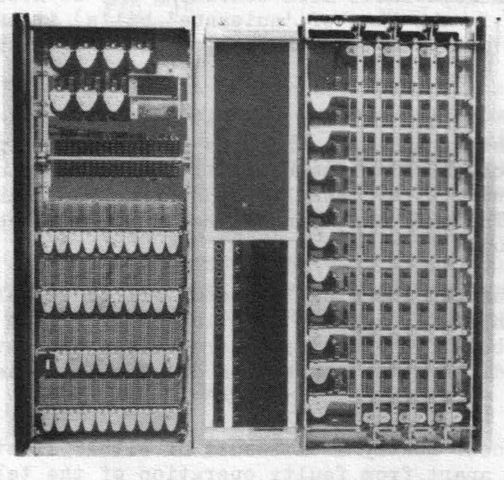


FIG. 91. PART OF CROSSBAR MECHANISM.

8. P.A.B.Xs.

8.1 Private Automatic Branch Exchanges are provided at many business houses, department stores and institutions. Some such enterprises have many hundreds of extension telephones and to provide each one as an exclusive automatic service would be cumbersome and costly for both the user and the Department.

P.A.B.Xs. allow extensions to dial each other direct or to dial out to the public exchange network. A manual board is also provided to answer incoming calls and direct them to the required extension, as it is not usually practicable to provide the means for callers to dial directly in to the extensions (this is done, however, in some P.A.B.Xs. for government and semi-government departments).

8.2 The various types of P.A.B.X. are:

- Unit Type P.A.B.Xs.

  Type C. - 25 extensions, 4 bothway exchange lines.

  Type CA - 50 extensions, 8 bothway exchange lines (an extension of Type C).

- Line finder P.A.B.Xs.

  2 Digit:
  - 50 extensions; 16 exchange lines (approx.) Often called Type E.
  - 90 extensions; 30 exchange lines (approx.) Often called Type F and is an extension of Type E.

  3 Digit - Over 100 extensions; exchange lines according to the subscriber's needs. Sometimes called extended Type F.

- Uniselector P.A.B.Xs.

  Generally more than 400 or 500 extensions, and where local extension traffic is fairly heavy.

Line finder and Uniselector P.A.B.Xs. have corded manual switchboards and the exchange lines are mostly in separate incoming and outgoing groups.

8.3 Except the Unit types, which have a unique combination of bimotional selectors and uniselector finders, the principles of selection are similar to those already described for public exchanges. Fig. 92 shows the trunking of a 3 digit Line finder P.A.B.X.

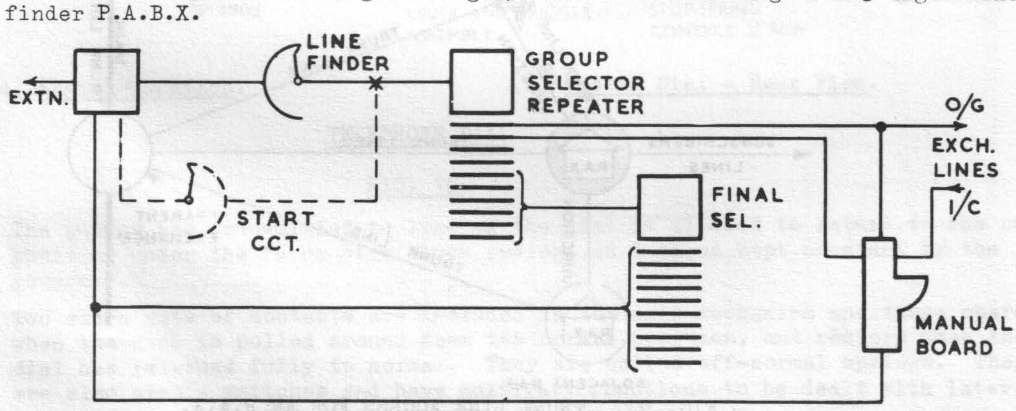


FIG. 92. TRUNKING OF TYPICAL P.A.B.X.

9. RURAL AUTOMATIC EXCHANGES (R.A.Xs.).

9.1 The telephone requirements of subscribers in country areas are much the same as those of suburban subscribers, but, because homes are more scattered, it is difficult to satisfy at reasonable cost the desire of country dwellers for a comparable service. To overcome these difficulties, Rural Automatic Exchanges were developed. There are now over 1,000 R.A.Xs. in Australia, giving a continuous automatic service to more than 50,000 subscribers, and these figures are being increased rapidly. In many cases an R.A.X. replaces several manual switchboards. A typical R.A.X. is shown in Fig. 93.

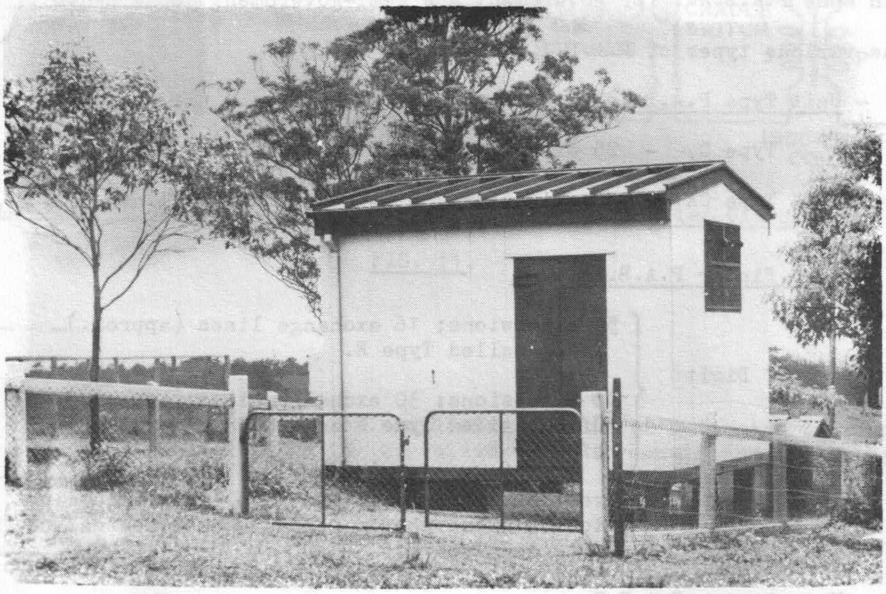


FIG. 93. A TYPICAL R.A.X.

9.2 R.A.X. subscribers obtain connection to other parts of the telephone network, via trunk lines to a distant manual exchange known as the Parent Exchange. Direct access may be provided to adjacent manual exchanges, or other R.A.Xs. within the unit fee area. Fig. 94 shows the possible trunk line access for an R.A.X.; a large proportion of R.A.Xs. however, have access to the parent exchange only.

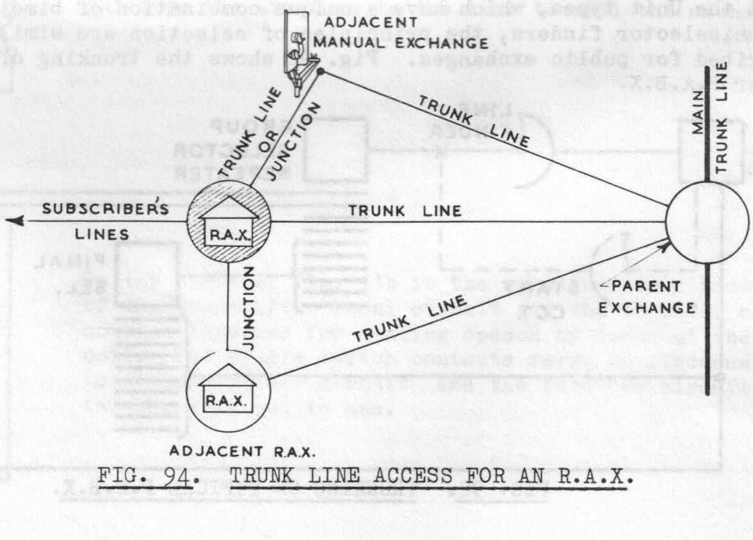


FIG. 94. TRUNK LINE ACCESS FOR AN R.A.X.

Except for occasional maintenance visits, R.A.Xs. are unattended.

The R.A.X. is a complete exchange of up to 200 lines (or slightly over in a few cases) and includes batteries, charging plant, alarms, and in many cases testing facilities also. The equipment is housed in a small building having wooden or steel framing.

9.3 Types of R.A.X. The first R.A.Xs. to be installed were designed in Great Britain. From experience gained with these units the Australian Post Office designed a unit more suited to our rural conditions. These were made by the British contractors, the first unit being installed in 1949 (Types C & D). A smaller unit was then designed in the A.P.O., the first of these being installed in 1951 (Type B). These are the standard types and only a few of the early types are still in service.

The units are generally designated according to size and type -

Type B, for units with a capacity of up to 50 lines, but which cannot be extended beyond this number.

Type C, for units with a capacity of 50 lines, which may be extended to 200 lines (by adding type D units).

Type D, for 50 line units used for extending type C installations.

9.4 The facilities available to R.A.X. subscribers are similar to those provided in a metropolitan automatic exchange area. The service, therefore, is continuous, secret, uses standard tones, and provides as required:-

- Service on the Following Types of Lines -

  Subscriber's metallic circuit (2 wire lines).

  Party lines (2 party, 3 party and 4-10 party).

  Bothway trunk lines to the Parent Exchange.

  Public Telephones (including multi-coin attachment for trunk line calls).

  Bothway trunk lines to adjacent automatic and manual exchanges.

  Single wire lines.

  Multi-office trunk lines (Omnibus Trunks). These trunk lines appear in more than one manual exchange; code ringing is used to signal the required exchange.

- Selective Metering of Calls by Party Line Subscribers. Calls made by party line subscribers are individually recorded, a separate meter being provided for each party.

- Revertive Calls on Party Lines. Calls may be made between any 2 parties of the one party line. The caller dials "1" to eliminate dial tone, and without replacing the receiver, rings the called party's code with the hand generator. This is termed a revertive call.

- Automatic Lockout of Lines Permanently Looped. The number of switching circuits in an R.A.X. is limited and these must be available for service as much as possible. Should a line become permanently looped (P.G.) it is temporarily locked out of service after a short delay - usually less than one minute. Normal service is restored to the line automatically as soon as the loop or fault condition is removed.

- Non-metering on Calls to the Parent Exchange. Subscribers are not charged a 'booking' fee on trunk calls and the trunk circuits to the parent exchange are modified to make them 'non-metering'. Public telephones are of the multi-coin type requiring prepayment for local calls, but a special dial is used which enables a P.T. caller to raise the parent exchange without first using pennies.

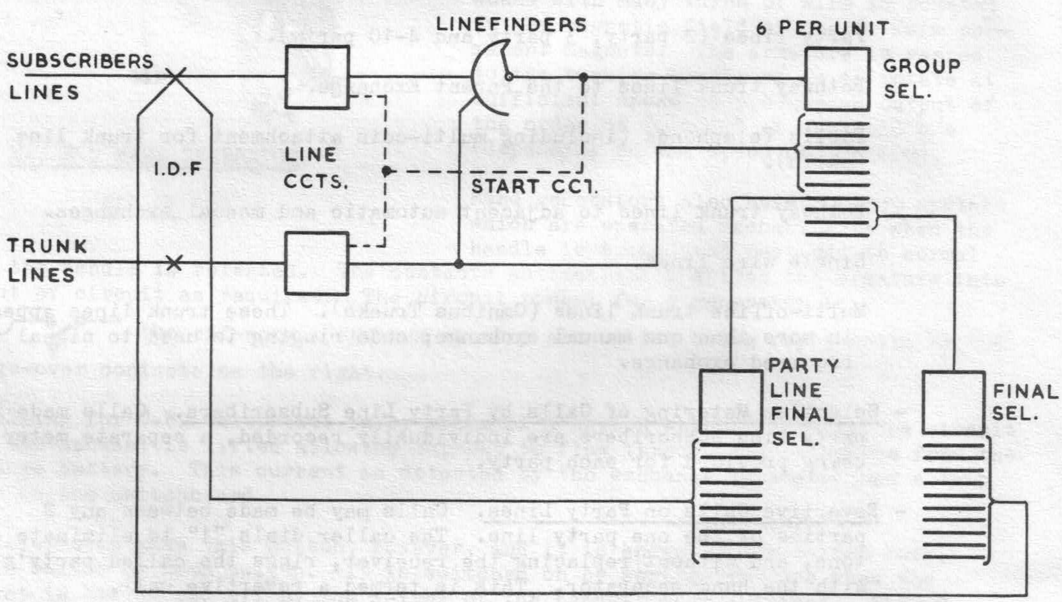
- Fault Alarms may be extended to, or detected from the Parent Exchange.

- Battery Charging Over the Trunk Line to the Parent Exchange. Where no commercial power is available at the R.A.X. this alternative may be used.

- Testing Facilities. Most units are equipped with a test set which permits subscribers' line testing and also routine tests of selectors. Some units provide for testing of subscribers' lines from the parent exchange.

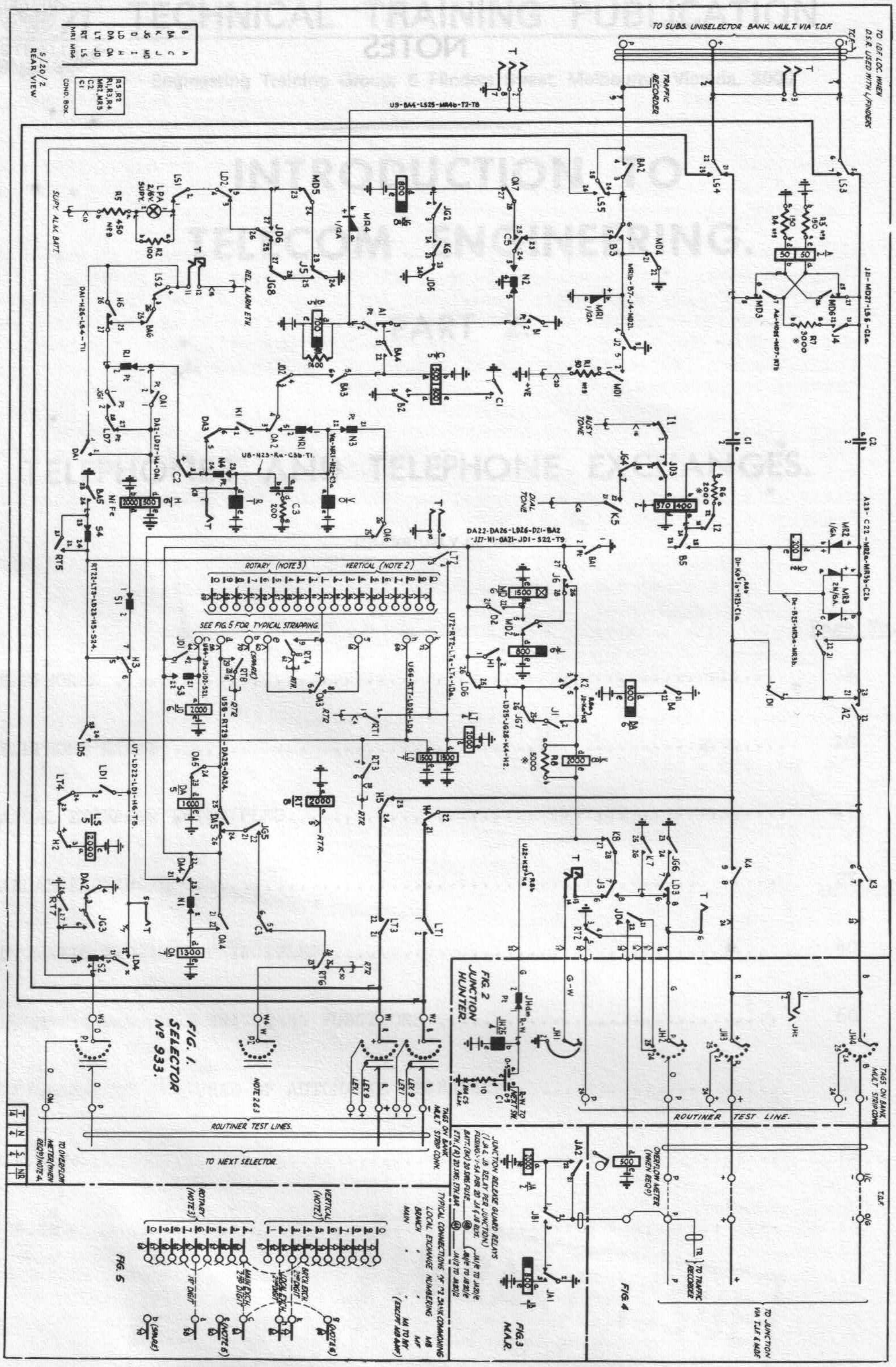
9.5 Trunking. The 40 line A.P.O. Type B R.A.X. uses no bimotional selectors and has a unique trunking system.

The Type C-D has more conventional trunking, many of the principles being similar to those used in metropolitan exchanges and P.A.B.Xs. Fig. 95 is the trunking diagram of an A.P.O. R.A.X. Type C.



TRUNKING DIAGRAM TYPICAL R.A.X.

FIG. 95.



EXAMPLE OF ROUTED SCHEMATIC CIRCUIT DIAGRAM.

(Typical of the hundreds of different circuits in an automatic exchange.)

NOTES